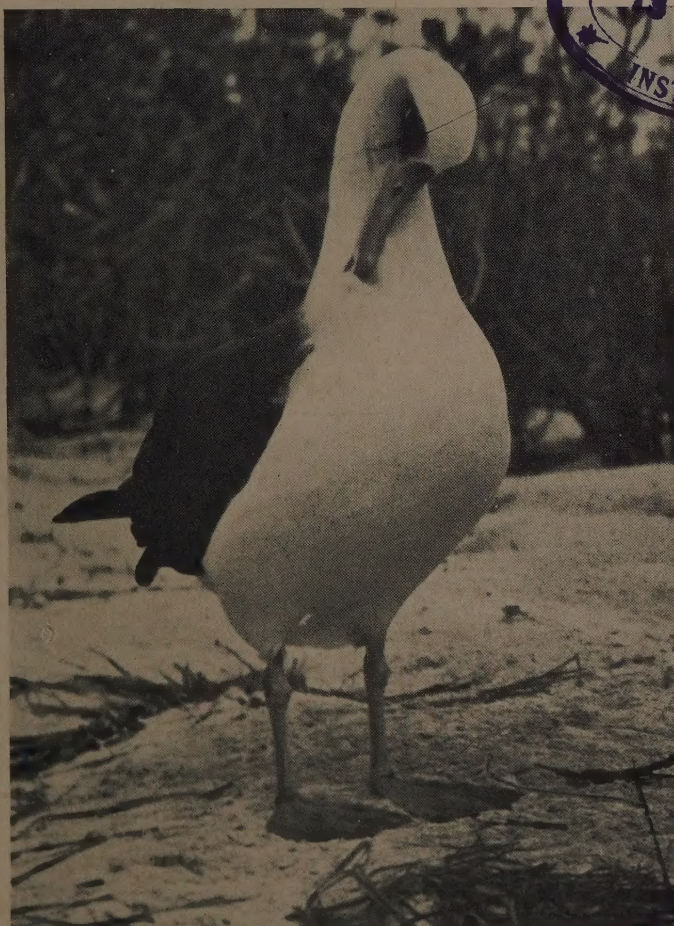
VOLUME XLV NUMBER 3

THE HAWAIIAN PLANTERS' RECORD



The Laysan albatross or white gooney, one of the most interesting inhabitants of Midway Islands.

THIRD QUARTER 1941

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

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THE HAWAIIAN PLANTERS' RECORD

Vol. XLV THIRD QUARTER 1941 No. 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Weed-Control Methods Influence Subsequent Weed Types:

A story of the way in which different weed control practices can influence the subsequent type of weed growth is aptly told in a series of photographs taken at the Wailuku Sugar Company.

Further Studies in Nitrogen Nutrition:

Time-of-Application-of-Nitrogen Test: A series of plots was laid out at Makiki to (1) study the effect of nitrogen fertilization on the growth and yields of the sugar cane plant, (2) study the physico-chemical and biochemical changes within the plant, and (3) derive therefrom information as to the reasons for variation in sucrose content of the plant. In a previous paper a report was made on the effect of nitrogen when applied in one application. In the present paper some of the theories advanced in the first paper are expanded and additional findings indicated as developed by multiple successive applications of nitrogen under growing conditions similar to those reported in the first paper.

Midway Islands:

The establishment of an airport at Midway Islands by the Pan American Airways Company in 1935 has resulted in making this American possession popular with large numbers of people who have since stopped there enroute to or from the Far East. An account is given of the geographical position, geology and modern history of the region, together with a descriptive narrative of the fascinating habits of the many birds that spend part or all of their time on the Islands. The author has studied the strange and interesting habits of the sea birds of Midway almost continuously for 6 years and has given an accurate picture of their various life histories.

Weed-Control Methods Influence Subsequent Weed Types

Through the courtesy of the Wailuku Sugar Company, we are permitted to present some interesting photographs taken by D. S. Judd within the ratoon areas of a field of 32–8560 cane.

The legends below the pictures identify plots which had been given different weed-control practices in the previous or plant crop. These may be briefly enumerated as follows: All plots received one hand hoeing, early. Thereafter, the "A" and the "B" plots were not weeded again, but the "B" plots received extra nitrogen fertilizer to compensate for that which was used up by the weeds. In the "Y" plots, subsequent weed control was by means of four sprayings with a standard herbicide, while at the same time the "X" plots received four hand hoeings.

It will be noted that a very different and distinctive type of weed growth has evolved from the differences in those methods of weed control which were used on the previous crop of cane. The prevailing weed in this current crop, on those areas which were not weeded in the former crop, is the soft, succulent annual type, whereas the tougher, more wiry grasses have persisted where herbicidal sprays or hand weeding had been the previous method of weed control.

(R. J. B.)

Fig.1. In the previous crop of plant cane grown on this area, the weed growth was not controlled. Note the abundance of the quick-maturing ''milkweeds'' which have survived and now dominate the area of this first ratoon crop of 32–8560 cane.

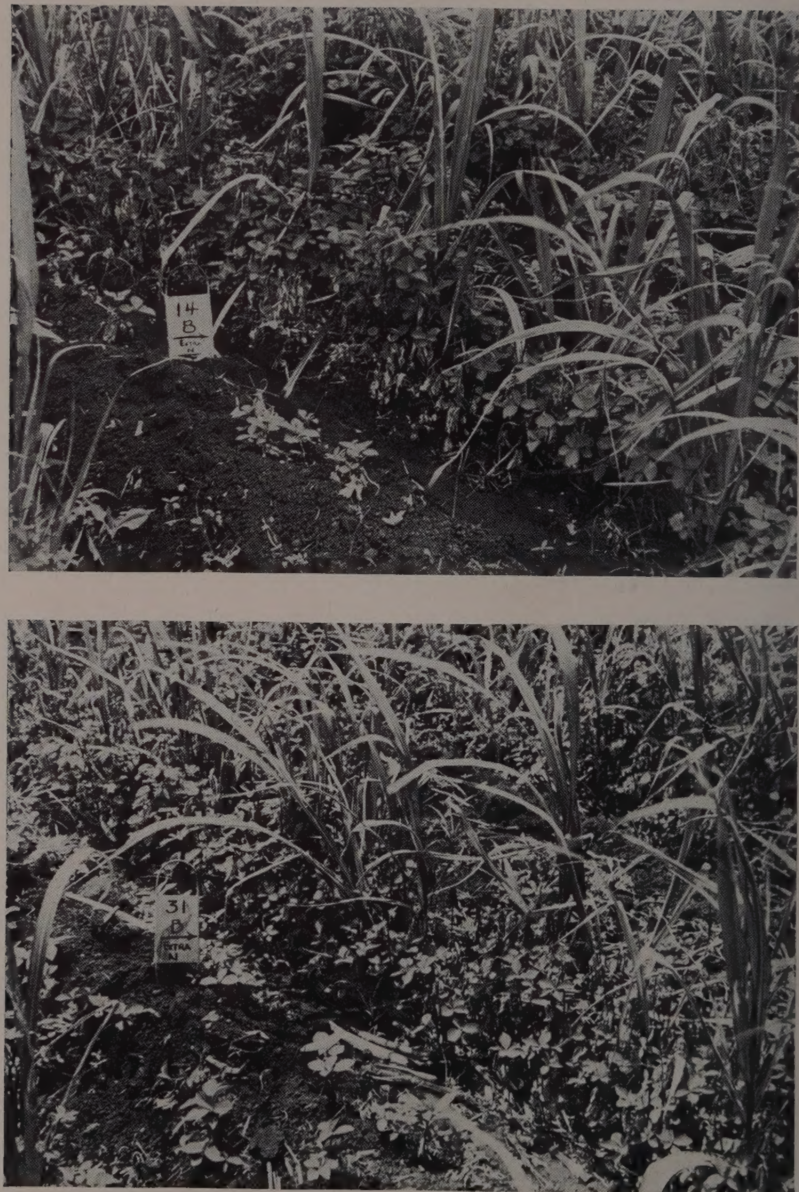


Fig. 2. A practice of no weeding plus extra nitrogen fertilization for the previous cane crop has also left its legacy of the fast-growing, succulent weeds which apparently are holding down the grasses.

Fig. 3. Where standard herbicides were used for weed control in the previous crop of cane, the succulent easily killed weeds have now disappeared and the tougher, wiry, grassy types have become more firmly established.

Fig. 4. Four hand hoeings to control the weed growth in the previous cane crop apparently conquered the easily killed weed types, but left a heritage of seed of the tougher grasses which are not so easily controlled.

Further Studies in Nitrogen Nutrition

TIME-OF-APPLICATION-OF-NITROGEN TEST

By A. H. Cornelison and H. F. Cooper

A discussion of the effect of varying amounts of nitrogen when supplied to sugar cane in a single application at the age of 1½ months was submitted in a previous issue of *The Hawaiian Planters' Record* (Vol. 44: 273–308, 1940), and a description of the plan and objectives of a series of three studies in nitrogen nutrition was given as the introduction to the presentation of the results from the first of these studies—the Amounts-of-Nitrogen Test.

The present paper aims to discuss the results from the second series of plots that was included in this investigation, i.e., the results which were the effect of nitrogen when supplied to sugar cane in multiple applications.

Treatments:

At the age of 1½ months a basic dressing of both superphosphate and muriate of potash, at the rate of 200 pounds per acre of P_2O_5 and of K_2O, was applied to all plots alike. Single plots were then given differential applications as follows:

Identity	Total lbs. N/Acre	Number and time of applications
E	400	In 10 applications of 40 lbs. N each at 2-month intervals.
H	250	In 10 applications of 25 lbs. N each at 2-month intervals.
G	250	In 1 application at 1½ months.
F	250	In 3 applications: 50 lbs. at 1½ months in July; 125 lbs. at 3 months in September; and 75 lbs. at 10 months in March of the second season.

The total amount of nitrogen given to Treatment E was known to be normally excessive at Makiki, but it was applied in this quantity in order to compare the results with those secured from the "D" plots which were discussed in the previous study and which had likewise received 400 pounds of nitrogen in a single application at the age of 1½ months.

Treatment H was supplied with a total amount of nitrogen which was believed to be optimum for Makiki under normal weather conditions. Its use in 10 bimonthly applications of 25 pounds each allowed good comparisons with the "G" and "F" plots, and to a lesser extent with the "C" plot of the former study which had received only 200 pounds of nitrogen at the age of 1½ months.

Treatment G which received 250 pounds of nitrogen per acre in one application at 1½ months of age was designed as the control for the "time-of-application" series of plots. While the behavior of this plot was not exactly the same as that of the "C" plot discussed in the former study, it was not too different to allow a general comparison to be made.

The application of 250 pounds of nitrogen to the "F" plot corresponded to normal plantation practice for cane crops started in May.

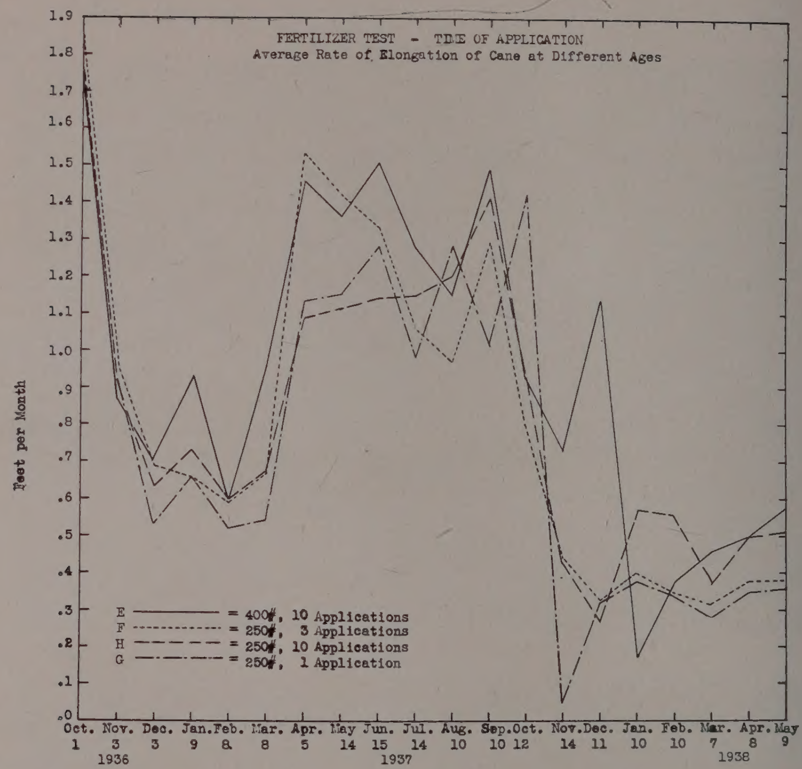

FERTILIZER TEST - TIME OF APPLICATION
Average Rate of Elongation of Cane at Different Ages
Feet per Month
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0
E = 400#, 10 Applications
F = 250#, 3 Applications
H = 250#, 10 Applications
G = 250#, 1 Application
Oct. 1
Nov. 3
Dec. 3
Jan. 9
Feb. 8
Mar. 8
Apr. 5
May 14
Jun. 15
Jul. 14
Aug. 10
Sep. 10
Oct. 12
Nov. 14
Dec. 11
Jan. 10
Feb. 10
Mar. 7
Apr. 8
May 9
1936
1937
1938

Fig. 1

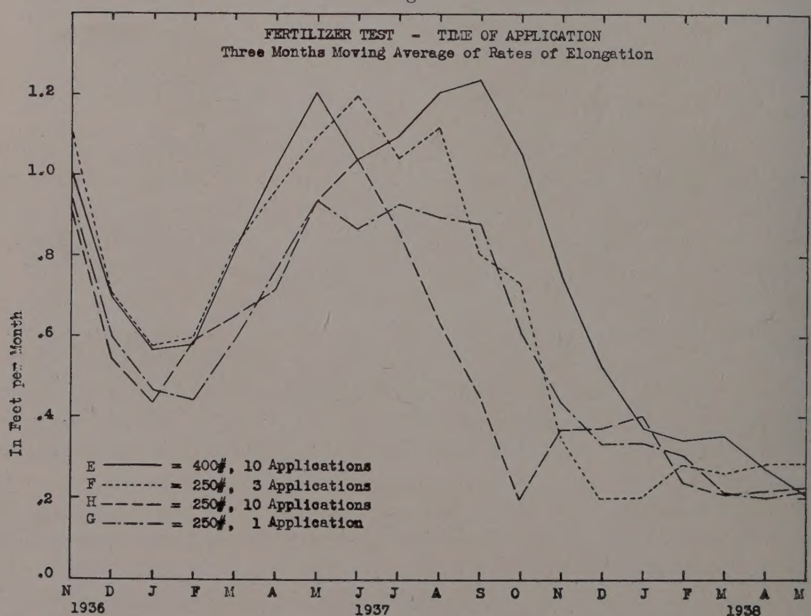

FERTILIZER TEST - TIME OF APPLICATION
Three Months Moving Average of Rates of Elongation
In Feet per Month
1.2
1.0
.8
.6
.4
.2
.0
E = 400#, 10 Applications
F = 250#, 3 Applications
H = 250#, 10 Applications
G = 250#, 1 Application
N
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
1936
1937
1938

Fig. 2

All nitrogen was applied in the form of sulphate of ammonia.

The same biochemical, physico-chemical and physical determinations were made on cane harvested from this series of plots as in the former series. Harvesting was carried out every two months and irrigation practices corresponded to those of the former block of plots, i.e., sixteen inches of water were applied per month throughout the crop life.

The "time-of-application" treatments were so effective that visual inspection of the field revealed the trends that were later found in the actual analytical data from the plots. As these differences in vegetative behavior were expected, they were followed closely by physical determinations in the field.

Total and Rates of Elongation (Figs. 1, 2, 3):

At one-month intervals growth measurements were made on 25 representative first-order stalks in an inside line of each plot. In general the average length of stick at each measurement was found to be approximately proportional to the total nitrogen which had been applied prior to the measurement.

The seasonal effects, as well as the general relationship of temperature to elongation as previously found in the "amount-of-nitrogen" test, also held in this series of plots.

As shown in Fig. 3 total elongation of the stalks in the various treatments was influenced not only by the amount of nitrogen applied but also by the timing of the application as well as the state of weather at the various seasons which the crop experienced during its life. In Figs. 1 and 2 wherein the rates of elongation are shown, the marked effects of seasonal temperatures are obvious as all treatment curves show decreased rates during the months of November, December, January, February, and March of the first year of growth. In the same months of the second winter (and further prolonged into the month of June) we also find decreased rates of elongation. Study of temperature curves for this second decreased-rate period indicates that not only season but also physiological age were the deterrents to growth therein.

It will be noted in Figs. 1 and 2 that rates of elongation, while reduced absolutely during cool periods, still maintain their relative positions as established by their prior nitrogen fertilization so long as age does not interfere.

The rates of elongation curves of plots "E" and "F" (Fig. 1) for the months of April, May, and June of the first year show also that the presence of recently applied, more adequate available supplies of nitrogen allowed these treatments to respond more rapidly to temperature influences, when these became favorable, than could plots "G" or "H".

The total-length-of-stick data (Fig. 3) indicate that although we can by a single heavy application of nitrogen at an early date ("G") get increased stalk length initially, we can by proper use of seasonal and age influences, and the same total nitrogen application, get greater total elongation of stalk over a two-year period as shown in the curve for "F" plot.

On first glance Fig. 3 would seem to indicate that possibly heavy multiple applications as in "E" would give the greatest cane yields since the stalks were so much longer. Exemplified herein is the inadequacy of total elongation figures when used alone as an index of cane growth. As will be seen later this plot produced actually

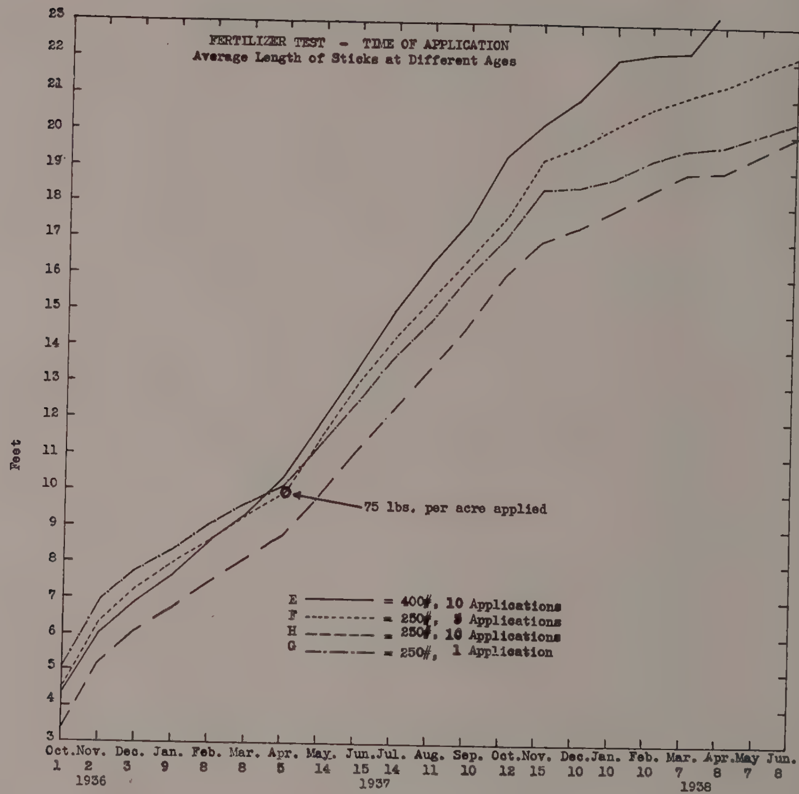


Fig. 3

little or no more millable cane by weight than did the shorter stalks in "F" or "G" plots.

It might be pointed out that by observation in the field, both "F" and "E" plots appeared more etiolated or slenderer and weaker stalked than the other two plots, especially in the second fall and winter. Thus one may infer that the additional stalk length did not represent true increases in growth.

In all three figures (1, 2, and 3) the complete inadequacy of small multiple applications of nitrogen as in "H" plot is apparent. This plot over a 22-month period received, however, the normal optimum Makiki application. Comparison of growths in this treatment with those of the "F" treatment point to the effect of timing on the efficiency of nitrogen applications.

The need for graduated applications of nitrogen as determined by the quantity of cane in the field, which we have deduced from the elongation and other data presented, will be covered in our "Discussion."

Stand of Cane (Figs. 4, 5, 6, 7):

The original stand of cane was again limited to 65 primary stalks per twenty-foot of line, up to and including the fourth month after planting. With this initial

equal stand at the beginning of the crop, whatever differences were found at each harvest after the fourth month were considered to have been due to the nitrogen treatment. Thus when the various age classes of cane were studied at each harvest, the effects of nitrogen on tillering, mortality, lodging, tasselling, elongation, and lala-ing were noted.

Much of the effect of nitrogen on juice quality at the final harvest was shown in our previous study to depend upon the prior vegetative behavior; this in turn is greatly influenced by the timing of the nitrogen application.

In the multiple-application plots secondary growth was high (Fig. 4). Parallel with this heavier tillering condition, the mortality of sticks from the original stand of "primaries" was less at harvest in these plots than where the single application was given (Fig. 5).

The number of dead sticks in treatment "F"—the plantation practice plot—was the lowest of all the treatments, and the millable, living population for all orders of stalks was the largest. A study of the data in Fig. 5 shows that in this "F" plot, after 16 months of age, the secondary growth was largely grouped into the millable-cane class, and that the competitive relations of the primaries and the secondaries were not conducive to death in either group. Due to this competition, however, there was induced a condition bordering on etiolation; more will be said of this condition later under "Yield of Cane."

As was noted in our former study, we again found the same causes of early mortality, i.e., a higher death rate when the nitrogen was applied in a single early application. No evidence was found that disease, insects, or mechanical injuries were responsible for this dead cane.

Composition of Crop—Suckers or Tillers (Figs. 4, 5, 6, 7):

The percentage of total millable cane composed of first-order sticks in the multiple-application plots is seriously affected about the fourteenth month by the inclusion of a considerable number of suckers or secondaries which had started in the previous late fall or early spring. The crop is thus made up of about 65 per cent first-order stalks and the remainder of more or less immature second-order stalks; this same condition was found also in a report made in 1936* in which multiple applications of nitrogen were supplied.

In the former study the single-application series of plots gave higher percentages of first-order stalks in the crop at all ages. This substantiates the general experience that tillering is increased not only by increased amounts of nitrogen, but also by continued nitrogen applications or availability. In addition to these sticks of secondary origin which finally become millable, a large number of suckers were started in the summer of the second year which were never to become millable and thus represented economic losses. These late suckers were more numerous and heavier in the two 10-application treatments ("E" and "H").

Although these sticks were of such a size as to force their inclusion in the millable-cane classification, their juices were naturally poorer than those of the primary or early started secondary sticks. Thus not only did a too long spread of

* Das, U. K., and Cornelison, A. H., 1936. The effect of nitrogen on cane yield and juice quality. The Hawaiian Planters' Record, 40: 35–56.

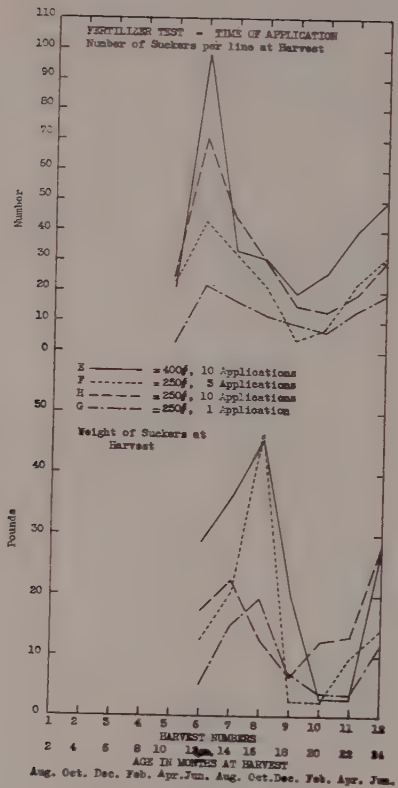


Fig. 4

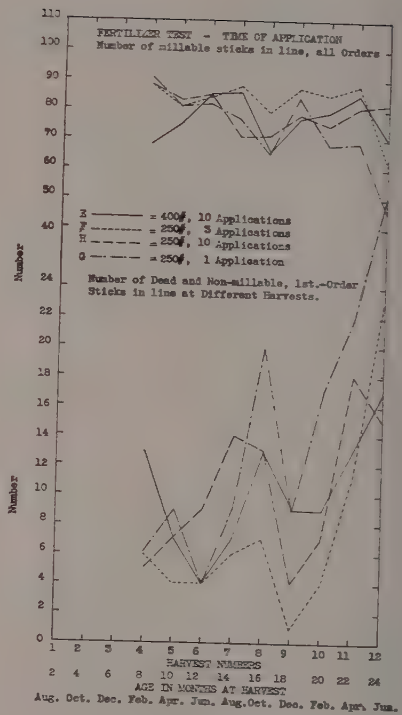


Fig. 5

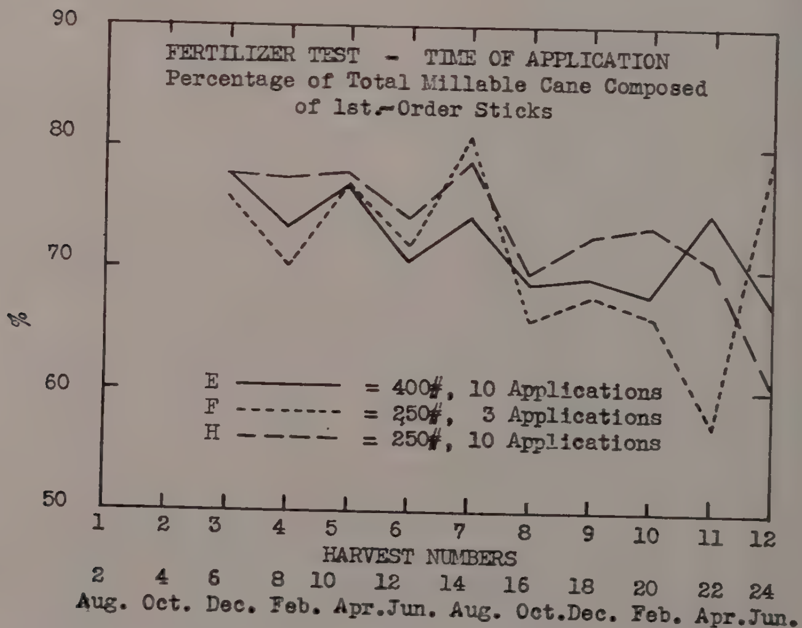


Fig. 6

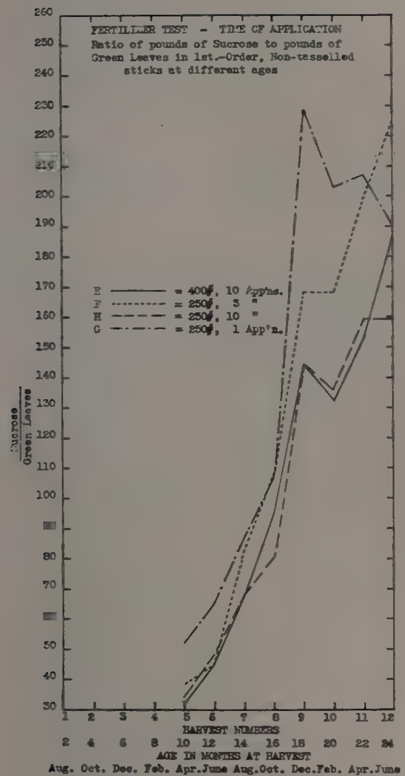


Fig. 7

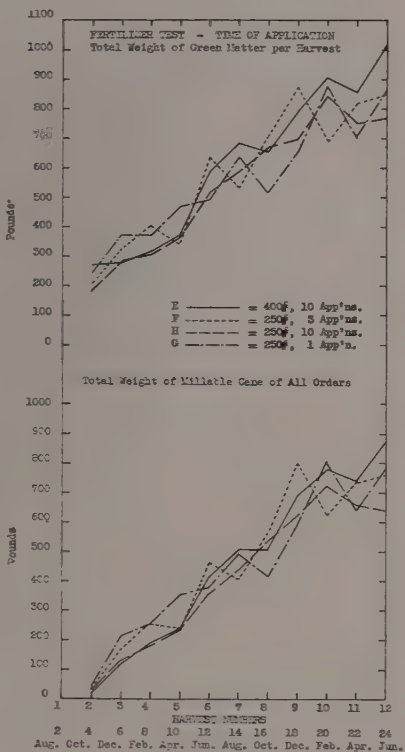


Fig. 8

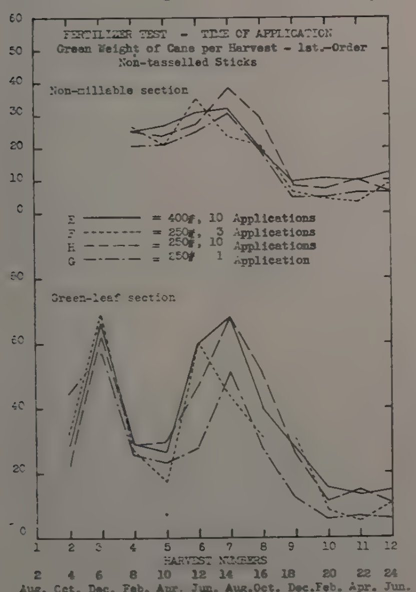


Fig. 9

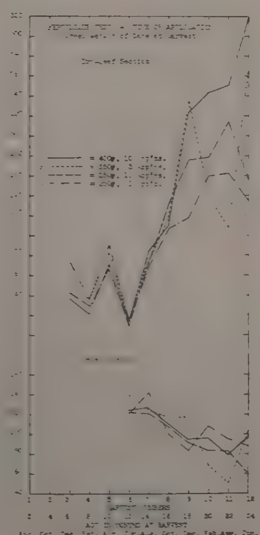


Fig. 10

the nitrogen applications produce juice of poorer quality, but it produced much non-millable tiller growth which was uneconomical.

The cane which received its nitrogen in many applications produced a higher amount of green top and leaf material which carries no recoverable sugar. This will be a factor where the present methods of mechanical harvesting result in this material going to the mill.

Yield of Cane (Figs. 8, 9, 10, 11, 12):

In harvesting, the cane in these plots was divided into season and age-of-cane groups in the same manner as the plots in the former "amounts-of-nitrogen" series.

The same three definite slopes of curves in the ratios of stick formed to weight of associated top were found as in the "amounts-of-nitrogen" test (Fig. 12). Closer examination of Fig. 12 shows that there is a definite proportional increase in non-millable top matter in the multiple-application plots over the single applications. Thus these plots appear to produce more leaf weight in proportion to the weight of stick formed at any age, as well as poorer sucrose concentration (in expressed juice), than does the single application.

The cane yields of first-order sticks from the season and age-of-cane sections of stalk (Figs. 9, 10, 11) show approximately the differences in weights that the growth measurement data led us to believe existed. However, when we consider total millable cane weights from stalks of all orders, we find rather small differences between the treatments except in the case of "H" plot in which growth was depressed.

The more we study the data for these age sections in the first-order sticks the more the conclusion is forced home to us that the timing of nitrogen applications allows us to choose the period of life in which we want our crop to make its maximum growth, controlled of course by season, age, and the temperature limitations imposed by location.

In the later part of the crop life, especially in the dry-leaf sections, we find that the weights of millable cane made in our multiple-application treatments are greater than those from the single-application treatments. However, if we go back to the early period of growth made in the "four-month section," we find that the "G" plot which had a single application is far in the lead in weight of cane formed—sufficiently far ahead to largely balance the continuous gains made later on by the multiple-application plots, at least up to about the sixteenth month after which the mortality, tasselling, and derangements in nitrogen metabolism exert their influences.

Juice Quality (Fig. 13):

As was the case in the "amounts-of-nitrogen" part of this experiment, the presence of supplies of available or applied nitrogen in the soil soon resulted in reduced purities of the cane juices. In the "H" and "E" plots, which received their nitrogen in 10 applications, higher water content of tissue and considerably higher quality ratio figures were found.

However, from Fig. 15 wherein are plotted the actual pounds of sugar recovered at each harvest, it is almost impossible to discern any great differences in yield among any of the treatments. Individual variations are greater than treatment effects when total pounds of sucrose are considered.

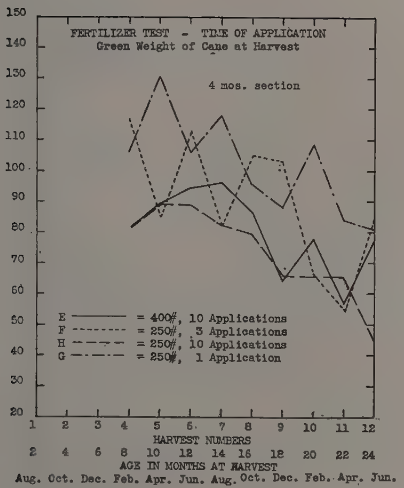


Fig. 11

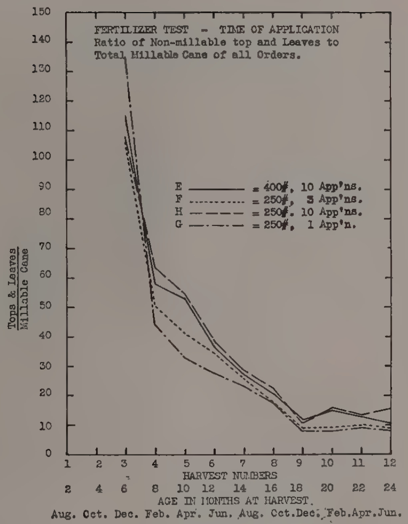


Fig. 12

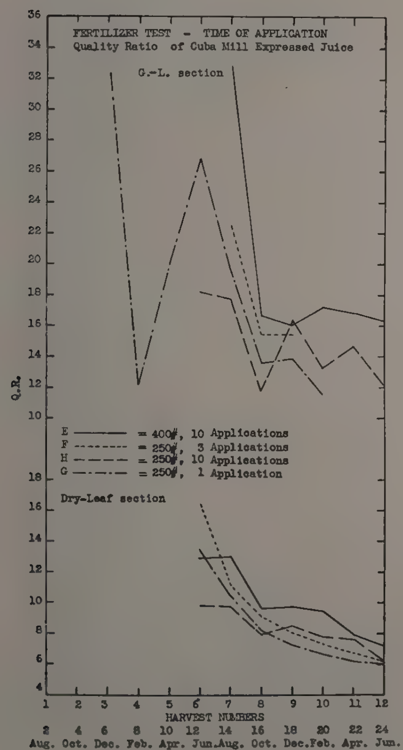


Fig. 13

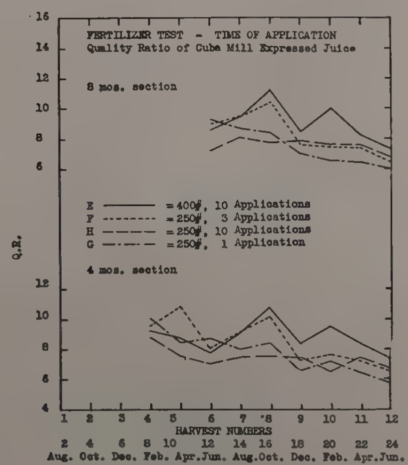


Fig. 14

As we have previously stated, juice quality is related largely to vegetative activity. Thus season, available nitrogen and age will be major factors to watch to improve juice quality. An adequate supply of water is also important, in that lack of it may act as a limiting factor in the responses to the stimuli of any of the other growth factors. However, we do not feel, from information obtained from our irrigation test (to be reported later), that large amounts of available water in the soil will *per se* induce very poor juice quality *without the activating influence of one or all of the other factors.* We found that we could improve juices by the removal of water some months prior to harvest (by drying off) only *when the cane is old enough and the season of the year is favorable for the retardation of growth and respiration rates.* This finding needs further study and a repetition of the test.

Water Content (Fig. 16):

The presence of a continuous supply of available nitrogen large enough to promote normal growth and, as in this case, multiple applications, causes sugar cane to maintain higher hydration levels in all anatomical parts later in life than the plant would maintain under a single nitrogen application. The higher hydration status so induced shows less age variations (in the multiple-application plots) than in the single-application plots.

This increase in water content is accompanied by changes in glucose and sucrose percentages. The plant tissues under conditions of higher hydration are also softer and more succulent.

The increased water content of tissues which received the higher nitrogen, as well as those exposed to smaller but prolonged nitrogen applications, appears to be associated not only with the activity of the living cell content but also with the condition of the non-living cell wall materials themselves. We found that dead, oven-dried material re-absorbed moisture from the air of the laboratory roughly in the relative proportions that were held by the tissues during life.

The so-called celluloses, hemicelluloses and other organic materials, therefore, must be considered as one part of the cause of the higher hydration values in high or prolonged nitrogen treatments. These determinations were not made, due to the large scale of these tests and the rather arbitrary chemical analysis methods for these materials. From ash analysis data obtained by A. Ayres we can only conjecture that the concentration of calcium, which was heavily increased as a result of increased or prolonged nitrogen applications, was the major inorganic swelling agent conducive to making these cell wall materials more capable of absorption of moisture. Fundamentally, of course, increased activity of nitrogenous protoplasmic materials, under continuous nitrogen availability, was the chief cause of the hydration of tissue, for it is within the protoplasmic complex that the qualitative and quantitative conditioning of the entire group of living and non-living cell constituents is controlled.

The data indicate that the permanent conditioning of the storage cell, in connection with its general sucrose and water-holding capacities, depends on the nitrogen which is available during the periods of formation and maturation of the tissues considered. It is possible, therefore, to influence permanently to a certain degree any set of joints in the stick by nitrogen treatment during the time of the

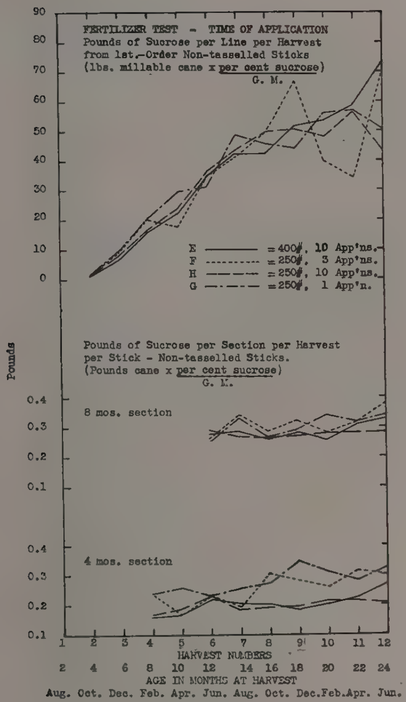


Fig. 15

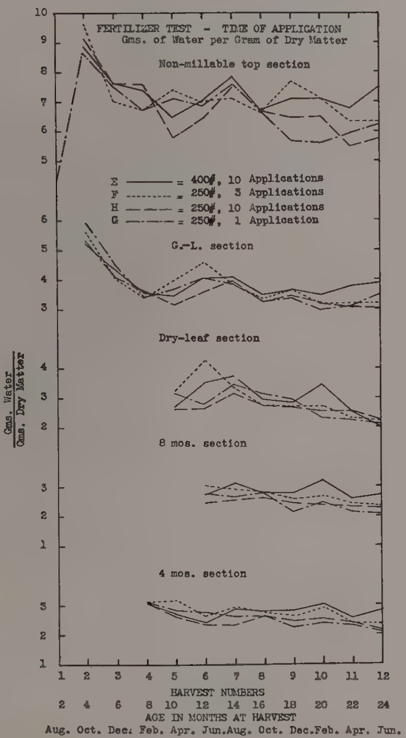


Fig. 16

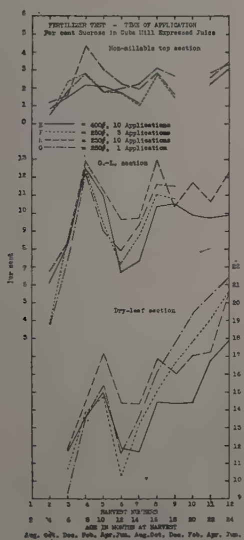


Fig. 17

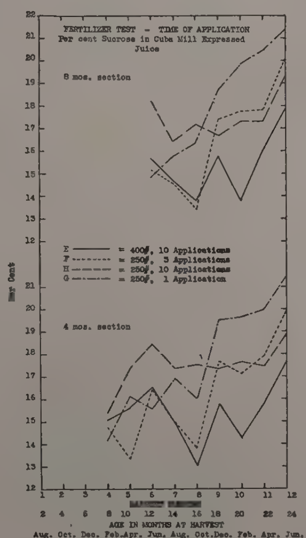


Fig. 18

development of those joints. Those which were formed at an earlier date show temporarily the detrimental effects of subsequent nitrogen treatment but these effects, as far as can be determined, are not permanent.

If we remember that a cane stick is primarily a phytomer and that each joint is a separate plant making up a formal community of plants, it is easier to grasp the conception that each joint or section of joints represents the accumulated effects of all growth factors operative at the time of its formation, plus the general physiological inheritance of the community as a whole. Thus if one were to conduct a postmortem on a stick of cane joint by joint one could trace, to a certain degree, its prior living conditions so far as water, temperature, energy, or plant nutrients were concerned. Therefore the growth conditions at the time of the formation of a section of stalk are, to a large extent, responsible for the limits of water and sucrose that can be stored in a given joint or section in a stick of cane. *The total cell capacity is established but not the final concentration of the cell contents.*

Sucrose Content (Figs. 18, 19, 20, 21):

The sucrose content of the cane was determined in two ways: (1) by polarization of Cuba mill expressed juice, and (2) by determining the percentage of sucrose in cane tissue on an oven-dry basis. The concentration of sucrose in juice was, as one would expect, lower in the higher nitrogen-treated plots and in those plots receiving continued applications. As long as the nitrogen in the soil was maintained at different levels, effecting thereby differential rates of growth, the levels of water content and sucrose content were directly affected, i.e., an increased growth rate was invariably accompanied by increased hydration and depressed sucrose concentration, while a decreased growth rate was accompanied by the opposite conditions.

When, through nitrogen shortage or seasonal temperatures a hindrance to growth occurred, the hydration status of the plants dropped to some extent and the sucrose concentrations of the juices increased. Age of the plant has great influence on this growth-response ability and, consequently, as the plant gets older the juices are improved regardless of treatment, although in their water content the tissues do maintain their relative positions with respect to their nitrogen treatments.

Many theories for the variation of sucrose concentration in juices have been propounded and presented in the past, but to cover them would hardly be feasible here. A thorough discussion of these theories is available in the technical report, Project D–1 at the Experiment Station. In the light of the findings in this series of tests, none of the older theories as discussed in our 1936 paper were satisfactory.

In spite of the fact that our knowledge is admittedly still very sketchy, we would like to present the picture of carbohydrate metabolism as it appears to us at present.

The number and volume of storage cells in a joint of cane depend on the growth conditions (determined by nitrogen, water, temperature, and so forth) at the time the joint was formed; number and vacuolar size of cells determine the total storage capacity or volume of the joint. Sugar is the primary construction material of these cells and their living contents. Cell wall materials thus represent a loss of potential stored sugar. To maintain life processes each cell uses up sugar for energy, thus presenting another loss of potential stored sugar. Associated with the living storage cells are the other non-living cell types needed to maintain and support the cell com-

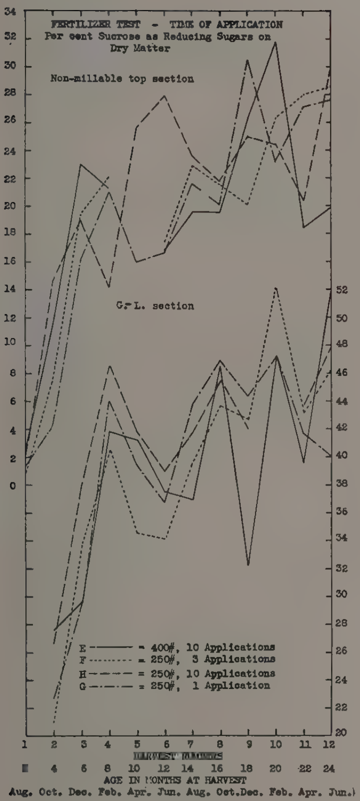


Fig. 19

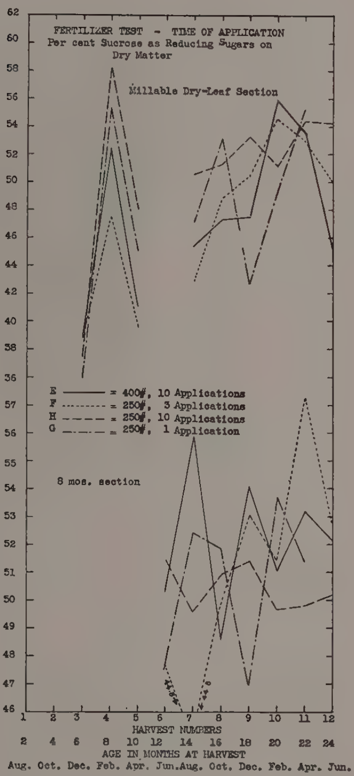


Fig. 20

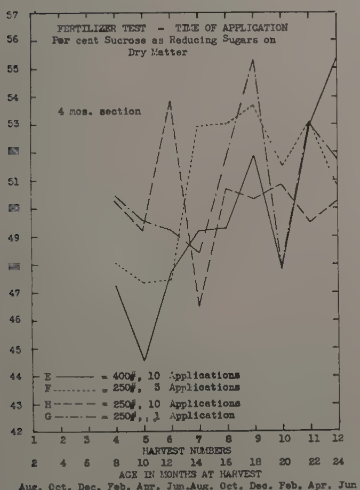


Fig. 21

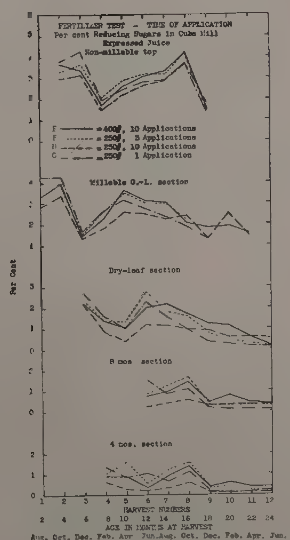


Fig. 22

munity in the stick; they also represent diverted potential stored sugar. Thus the sugar stored represents the difference between the amount available from the process of photosynthesis and the amount used up in cell construction and respiration.

In the analyses of samples of cane tissues or juices, reducing sugars are invariably found present. The amounts of reducing sugars present may well serve as a rough index of the growth rate of the cane plant, for during accelerated growth they are increased. Sucrose percentages in the plant are inversely correlated to the reducing sugar percentages although the relationships are rarely proportional, i. e., the losses in sucrose are not compensated for by, but are usually greater than, gains in glucose.

In plants other than sugar cane, glucose has been assumed to be the movable form of sugar, later on condensing to the more complex carbohydrates in the cells. With microchemical methods it has not been possible to identify reducing sugars in the fibrovascular bundles of H 109 cane sticks. Thus we are faced with one of two probabilities: first, that the sugar moving in these vessels was not glucose but sucrose (or some other non-reducing sugar form) and second, that if the sugar were glucose, i.e., simple reducing sugars, the mode of movement was of such a nature as to make it impossible to determine glucose by the methods which we employed. We did find, by microchemical methods, glucose to be present in appreciable quantities in the cytoplasm of storage cells and this fact may account for the considerable percentages of glucose found in expressed juices. In the light of these conditions we were led to the conclusion that reducing sugars present at any time in the mature stalk tissue largely represent the remnants from inverted sucrose which had been utilized in the metabolism of the cells. The higher the vegetative activity of the cell, the more energy it requires and consequently the more sucrose will be withdrawn from storage.

In older sections of the stick the rates of utilization of sucrose were lower and consequently less reducing sugars were needed to fill constructional or respirational needs. The storage space in the cells was also somewhat increased by a reduction in volume of protoplasm (and its absorbed water). Sucrose could be moved from the top into these matured cells and the sugar content of the section of stalk improved not only relatively but absolutely. With removal of nitrogenous compounds from the older cells for probable re-use in the region of the growing point, the protoplasmic contents of the cells, which are highly hydrated, lose some of their volume and activity, and sucrose can replace the withdrawn materials resulting in not only less water but more sucrose in the cell. The theory of a more-or-less-"static" cell, so far as total sugar storage is concerned, which was proposed by Das in 1936 is considered untenable and is now believed to be a "dynamic" cell, the storage capacity of which is fixed, as formerly, but the contents of which at any time are governed by the factors operative in promoting all phases of cell activity. In the joints of the green-leaf section and the recently formed dry-leaf section, the cells are younger and more active, with relatively poorer sucrose content per unit volume of cell storage capacity. Thus, primarily, improvement of juice quality is the problem of bringing the largest number of joints in the stick to the lowest degree of vegetative activity through the application of some limiting factor such as age, season, water, or fertilization, which may depress cell activity.

In the 1936 study nitrogen was tacitly blamed for increases in hydration. These hydration increases caused not only dilution of juices but also influenced the

mechanism of carbohydrate metabolism. At this time it is still felt that nitrogen is the causative factor, but it is now uncertain as to whether the sucrose is first inverted and used and then water enters the cells as replacement or, *vice versa,* if a concurrent combination of the two are operative.

More work is needed on the translocatory forms of carbohydrate in the plant to substantiate our findings regarding glucose in storage and fibrovascular tissues, for we realize that the quantity of a material to be found in the fibrovascular tissues is a possible function of the speed of movement or use of such material. The lower the amount which may be found present, the higher the postulated speed of movement must be to translocate a given mass through a small vessel. It may have been possible that we were confronted with this problem in our study of fibrovascular material and were not able to obtain visible chemical concentrations in cane tissues for that reason.

As already mentioned there is good reason to believe that the cell wall materials laid down in times of rapid growth, as contrasted with slow growth, are at least physically different and perhaps also chemically different and, *per se,* possess different water-holding capacities. As was proposed in the 1936 study, it is quite likely that inorganic salts influence this physical condition and that probably calcium is the largest contributor. Removal or replacement of excesses of this basic swelling agent which occur with advanced age could then influence the course of cell hydration and sucrose concentration, as our work seems to indicate.

In the 1936 test the data obtained seemed to point to interconversion from one carbohydrate form to another as a result of variations in the hydration status. The present conception does not completely obviate the former idea, but does considerably modify it to allow for changes in sucrose concentration which are too large to be accounted for by interconversion. As a matter of fact the data collected in this series of tests tend to relegate this sucrose-hemicellulose inter-conversion (if it exists) to an unimportant position as a factor for the variation of sucrose percentages and amounts in sugar cane.

Glucose (Figs. 22, 23):

As already mentioned, data for glucose, water content, and growth rates show parallel responses and in general are opposed to the curves for the sucrose concentration in the plant. If we assume that glucose in the stick were being condensed to sucrose for storage as well as meeting the needs of respiration, then at those times in the rapid-growing months when it occurs in highest amounts, we should theoretically find increases in sucrose concentrations—*which we most assuredly do not find.* If we assume that the glucose is increased in the summer due to conversion from both sucrose and hemicelluloses, we should find losses in both sucrose and sugar-free dry matter in a given section of stalk material. In this test we find, within the error of analyses, only reduction in sucrose. This reduction in sucrose is out of proportion to the glucose found at any time on an absolute pound basis in a given section of stalk, thereby indicating its removal or loss by respiration. It must also be remembered that at the same time sucrose concentration increases in older cane material, the cells in the same material become thicker walled, harder, and more lignified. If celluloses and hemicelluloses are to be considered functionally as

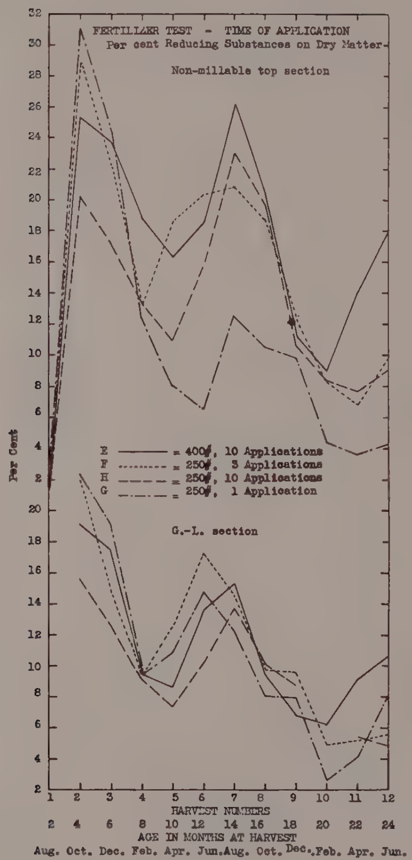


Fig. 23

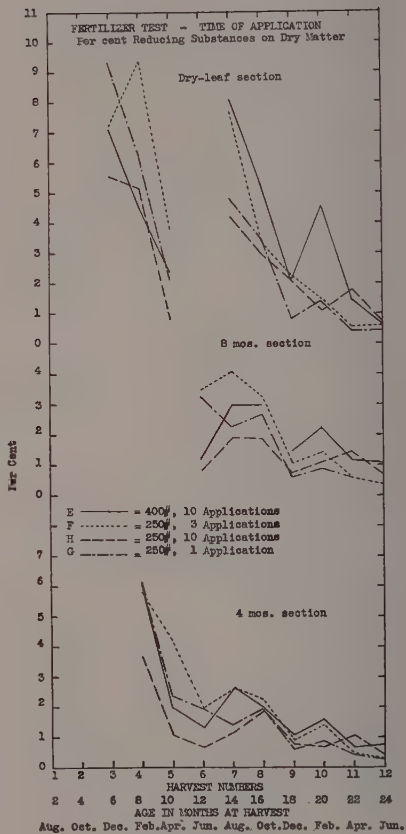


Fig. 24

cell wall materials, how is it then possible for the cell walls to become toughened, if fractional parts of them are being removed to satisfy the increased sucrose percentage in the cell—a condition which we do find with increased age?

The only reasonable explanation of this situation lies in the conception of the "dynamic" rather than the "static" cell. In the case of the dynamic cell there is a continual flow of sugar from the leaves to build mature cell walls, to satisfy respiration losses, and to attempt to maintain "normal" sucrose storage in the cells. Only on this conception of the living cane stick do all facts fit together. When growth and respirational demands under seasonal or fertilization stimuli interfere with the flow of sugar downward from leaves, losses in stored sucrose are encountered in the lower portions of the stalk due to the metabolic demands of the plant parts adjacent thereto. When the growth demands drop, through the effect of any limiting factor becoming operative, the leaves can then meet local consumption demands in the apex, and any excess sugars formed go to the replacement of losses formerly sustained in the older parts of the stick.

If it is possible to apply knowledge gained from other plants to the cane plant, respiration rates and growth respond to the same stimuli. The demands for sugars made by increased respiration in times of good growing conditions further accent any shortage of the supply coming from the leaves. Thus, using glucose as a respiration index, we have a useful weapon to apply in measuring the maturation of a given section (or whole stick) since, while it does not represent sucrose losses quantitatively, it does measure relative rates of loss or indirectly the ability of the cells to use stored or incoming sugars.

Electrical Conductivity of Juice (Fig. 25) :

In the 1936 report the conductivity figures were employed as a measure of the ash materials in the plant saps, since this method had been accepted by plant physiologists in general as satisfactory. From the data of this present test wherein the conductivity of juice as well as the percentages of ash in the tissues were determined, we have come to look askance at the validity of the conductivity data for ash measurement. As a matter of correction of the 1936 conclusions, it appears that increased applications of nitrogen do not cause an increased concentration of ash, but just the opposite. Thus it appears now that the increased conductance found at that time in the high-nitrogen plots, especially in the mature cane sections, was due to accumulations of acidic radicles of which no small part was probably organic. The increase of acidity and conductance of the saps with age, accompanied by a decrease in per cent of basic ash constituents in the same sections, can only point to a piling up in old tissues of acidic-type materials. It is to be regretted that chlorides, sulfates, silicates, and phosphates were not determined, as it might have been possible to localize the preponderance of the effect in the organic or inorganic acid classes as the case may have been. There is a strong possibility that a buffering action of organic on the inorganic acids may also have taken place. This would allow the conductivity figures to indicate differentiation, as they do, while at the same time masking any possible treatment differences on the pH of the same juices.

The conductivity measurements of juices when compared with the pH measurements lead one to hypothesize that there is a greater quantity of organic acids in plants fed with prolonged or high-nitrogen applications. As far as we know, no one has analyzed juices quantitatively for chlorides, sulfates, phosphates and so forth, nor has anyone tried to correlate quantitatively these acid constituents with the basic constituents. Ayres has collected data from this series of tests which point to a removal and loss of ash materials from the plant in the leaf as it is abscissed. Are the inorganic acidic radicles also removed from the plant by this mechanism or do they tend to accumulate with age in the plant? It would seem reasonable to suppose from our pH data that some of the inorganic salts on entering the plant would be decomposed, thereby releasing inorganic acid radicles which were either absorbed on colloid surfaces, or entered into combinations with organic materials in the cells and so were accumulated (but buffered in effects on pH).

Another factor in comparisons of total ash and conductivity must be remembered, and that is that conductivity will measure ash constituents in a soluble ionized condition only, whereas total ash will measure additional mineral material

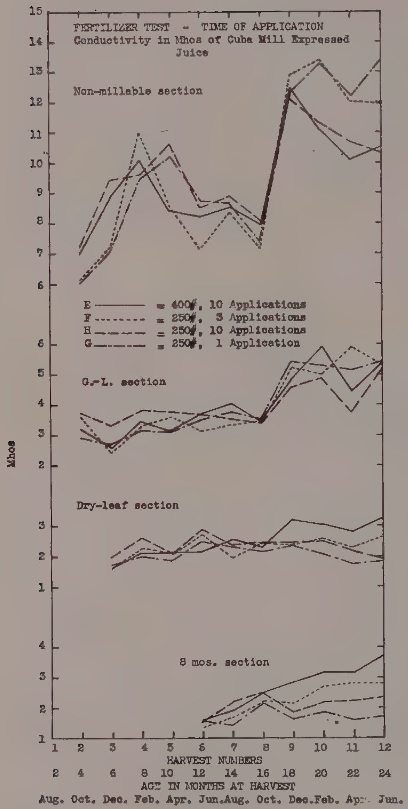


Fig. 25

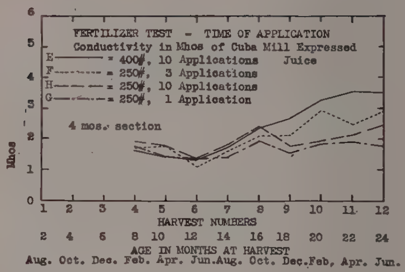


Fig. 26

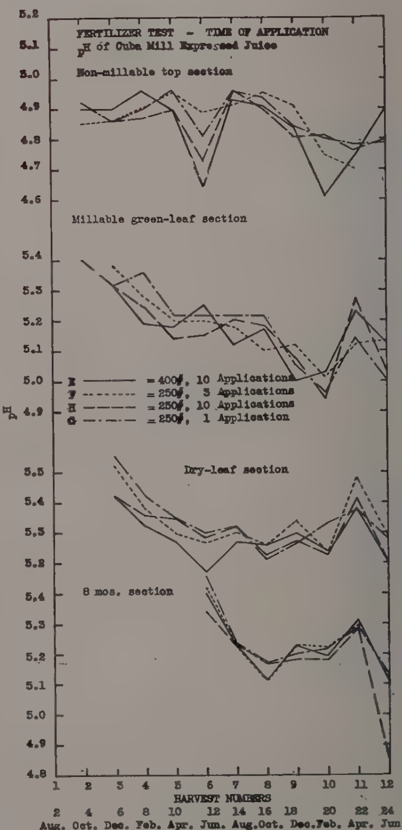


Fig. 27

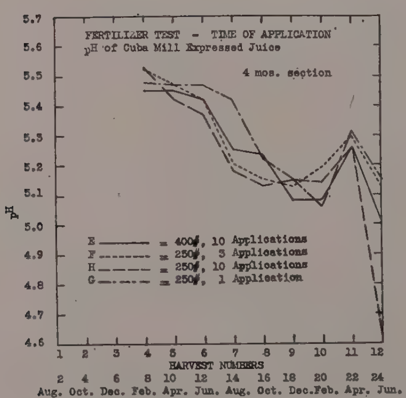


Fig. 28

built into cell structures and largely insoluble (except after ashing or hydrolysis by acids).

The non-millable top shows large seasonal variation in concentrations of electrolytes but no fluctuations due to treatment. The tops formed during the winter show high concentrations of electrolytes whereas in the corresponding summer-formed tissues the concentrations are low. In mature dry leaf, 8-month and 4-month sections there is only a slight seasonal trend in such concentration but there are good trends due to age and treatment, especially in the last part of the crop life. Hydration of tissue decreases steadily in the older mature sections and may account for part of, but probably not all, the apparent increases in salt concentrations in juices. The unaccounted-for salt increments in the juices are present in greater amounts in the higher nitrogen treatment and when the nitrogen applications are prolonged throughout the life of the crop.

In general, Ayres' determinations of ash in these canes indicate a directly opposite set of conditions so far as per cent total ash in *the plant* is concerned. As a consequence of this, it must be inferred that the functions of the ash constituents within the plant, and possibly their location in the cells, may vary with the nitrogen metabolism level of the plant, for at least it appears that their physico-chemical properties are different.

Samples of cane juice from the Cuba mill were electrodialyzed and some qualitative tests were run on the resultant solutions. As would be expected considerable quantities of chlorides, sulfates, and phosphates were found to be present in the acid chamber; ammonia, calcium, potassium, magnesium and some form of organic nitrogen (which was not free ammonia but which readily decomposed at high pH to yield ammonia) were found to be present in the basic chamber.

The undialyzable residue of sugars, proteins and other compounds of large molecular size yielded a solution which was highly acidic. On analysis for total nitrogen this solution yielded about one eighth to one third of the nitrogen in the original juice. The soluble, ionizable ash constituents were almost completely removed from this fraction. We found that the electrodialysis of even the thick, heavily discolored saps from the cane tops yielded beautifully clear juices. Apparently due to the relatively more rapid removal of basic materials in electrodialysis, the solutions passed through acid isoelectric points of the proteins and suspensoids which were soon flocculated and precipitated in a curdy mass leaving the juices in a clear state. The conductance of these dialyzed juices was greatly reduced and approached the figures for sugar and water solutions of the same concentration. Because we did not obtain neutral solutions in the center (or dialyzed juice) cell we suspect the presence of a set of large molecule acids.

The electrodialysis method should be investigated further at some time as it may be an approach to the separation of adsorbed ions from the colloids of the cell, or at least an approach to a method of separation for the study of nitrogen fractions which are not in the protein or polypeptide groups (large molecules).

As can be judged, we know little or nothing as to storage forms of nitrogen in the plant, chiefly due to a lack of methods of separation which will not involve decomposition enroute to quantitative determinations.

pH of Cuba Mill Juice (Fig. 27):

There are no discernible treatment differences in the acidities of juices of the various treatments at any harvest or age. There is, however, the same gradual decrease in pH (increase in acidity) with increasing age of a given section of stalk or of the stalk as a whole.

The acids were not fractionated nor was the total titratable acidity obtained, so that it is not known to what group of acids or compounds (organic or inorganic) the increased acidity is due, or where, within a cell or community of cells, the compounds which are responsible may be located. Under "conductivity" a discussion was presented dealing with the possible organic origin of this acidity. It must not be forgotten, however, that when the juices were electrodialyzed, chlorides, sulfates, phosphates (and probably some silicates) were obtained. The latter two acids form complex salts yielding one, two, and sometimes three hydrogen ions in solution which can easily affect the acidity.

An attempt was made to determine pH in living tissue by using intravita range indicator dyes and a microscope. The cell walls and the penetrable lamellae of the cytoplasm all gave reactions closely in accord with the pH of juice data, but it was not possible to determine the pH of the stored sucrose or vacuolar saps. In cases where the cell was "killed" (during or after staining) either an increase or decrease in pH would be effected. Due to the impermeable interfaces established in the cytoplasm of the living cell, it was not possible for the large molecule dyes to penetrate these "living" colloidal membranes into the vacuolar storage cavities.

The acid reactions of cell wall material and cytoplasm, and the increase in acidity of juices with age, perhaps arise from increases in adsorbed organic acids which are themselves derived from sugars used in respiration. However, the question is still wide open in all of its phases and will probably remain so until such time as the physical properties of the cell colloids are better understood.

In studying the conductivity curves along with the pH curves there appears to be higher adsorption of ions in the higher nitrogen treatments and in plots continuously fed with nitrogen (where cytoplasm is somewhat more bulky when viewed microscopically). This adsorption may be the mechanism by which buffering of acids arising in respiration is effected, i.e., they are bound in a partially un-ionized condition, thus accounting for the lack of differentiation of pH between treatments for a given age of plant.

General Observations:

In general we feel safe in stating that the cell community in a joint can never be considered static; changes are continually taking place up to the point of "death" (not to mention afterward) of all cells in a stick.

As an example we found that with increase in age there was more and more a deposition of lignin-like compounds in and around fibrovascular tissue—a hardening of the fibers, so to speak, up to the time of tasselling. After tasselling, however, there was a sudden change in the activity of these cell groups from deposition to that of removal. Lignin is known to be one of the most stable constituents in a plant cell, samples estimated at over half a million years in age having been found unchanged chemically. So far as we can find there is no enzyme known which is

effective in splitting lignin. Yet quite definitely, as a result of tasselling, much of the lignin was lost from the fibrovascular tissue, causing the bundles to become more flaccid than formerly. The rind became softer and was more easily penetrated because the tissue remaining, after the decrease in lignin (due to tasselling), was mainly cellulosic in character.

How is the plant able to move the lignin and to where is it moved? In general, considerable amounts of lignin (along with considerable amounts of silica) were found, through microchemical methods, to be present in the tassel arrow. The lignin may have been moved there; if so, the *mode* of movement of both these materials remains a wide-open question.

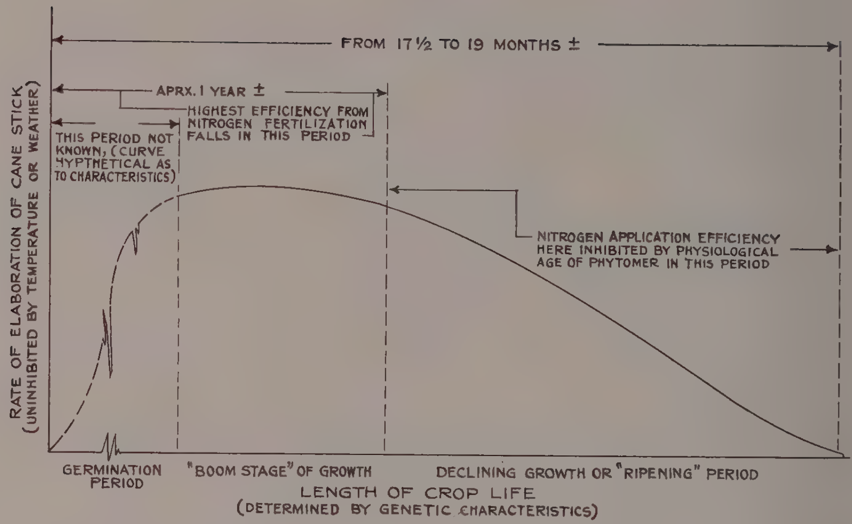
The change in lignin status, due to tasselling, was effective throughout the stalk, from the apex to the very butt regardless of the length of the stick. The writers have been able to distinguish between tasselled and untasselled stalks from butt sections of the stalk alone, even in some unfamiliar varieties and hybrids. This condition dealing with the lignin of tasselled and untasselled stalks has already been investigated and reported by D. M. Weller, Project P–13 at the Experiment Station.

Discussion:

It becomes apparent that the effect of nitrogen fertilization on the sugar cane plant, all other plant growth factors being non-limiting in magnitude, is controlled by two major conditions: (1) weather (particularly sunlight and temperature), and (2) physiological age of cane.

Under differential nitrogen applications, the quantitative responses in H 109 cane and sugar yields to be expected have become evident only when the average of the day and night temperatures is above a minimum of 67° F. Below this average temperature growth does not cease but no large acceleration in elongation due to nitrogen fertilization is obvious. This temperature of 67° F., it will be noted, is an *average of day and night data* and must not be confused with the 70° F. base of the Das' day-degree method of evaluation wherein the diurnal maximum temperature is used regardless of its duration. It is obvious that there was a *maximum temperature of 70° F. or over* for us to arrive at a 67° F. average of day and night temperature when we have a six to seven degree diurnal-nocturnal range at Makiki. In other words our findings regarding average temperatures and growth rates upholds Das' day-degree base of 70° F. maximum temperature from which an approximate straight-line correlation of growth with temperature may be calculated. An average day and night temperature of 67° F. seems to be the exact point at which accelerated responses due to nitrogen treatment first become evident in H 109 cane (and 31–1389), and for this reason we feel it worthy of mention. While we have no data to support the theory, observation would indicate that this threshold temperature will be different for different varieties of cane.

Our data point to the normal growth-rate curve of cane, when uninhibited by weather or season, as being an inverted parabolic curve, the spread of which on the time axis is controlled by genetic characteristics. The curves presented below theoretically approximate the picture as we see it for non-tasselled H 109 stalks.



The timing of applications of nitrogen to the soil is governed by three factors: (1) the capacity of the plant to take up and hold in reserve nitrogen supplies for use in subsequent tissue formation, (2) the ability of the soil microorganisms and colloid complex to furnish nitrogen to the plant from soil "reserves" and from the applied fertilizer, under variable conditions of soil temperature, and moisture, and of microorganic activity, and (3) the weather conditions available for growth.

The first factor, capacity of the plant to hold nitrogen reserves, is a matter of the volume of plant material and the concentration of nitrogen which we are able to pour into this capacity without toxic effects. It must be borne in mind that anatomical parts differ widely in capacity in this regard. There is also considerable genetic difference in storage ability among varieties which will have to be watched.

In all our tests we find that the cane plant, under conditions of either nitrogen excess or deficiency, holds very close to a common range of nitrogen content, indicating that storage leeway per unit volume of plant tissue may not be very wide. Excessive amounts are definitely not taken up by the plant. This indicates some sort of either organic or inorganic fixation in the soil, or losses through leaching. *Thus with limited storage space in the plant, nitrogen must be quantitatively applied to correspond to the plant volume available.* In other words we should graduate our fertilizer applications according to the size and number of the stalks in the field and apply the nitrogen within the boom stage, taking into account the time lag between application and complete uptake, and the lag between uptake and completion of resultant growth. We have found the uptake period to be about three or four months for normal applications under good growth conditions at Makiki. The resultant prolongation of growth is generally proportionate to the amount taken up.

As to the second factor, the ability of the soil complex and soil microorganisms to feed nitrogen supplies to the plant, we have hardly scratched the surface of the subject. At Makiki we know that the soils involved in these tests had a more or less constant available nitrogen content of from 12 to 17 pounds per acre, as measured by RCM, after the first flush of nitrogen in the fertilized plots had been

lost. This seems to be the general nitrogen status of Makiki soil whether fertilizer is applied or not. The picture seems to be a sort of equilibrium between available and non-available nitrogen reserves, which is a characteristic of the soil type and environment.

The growth obtained in a zero-nitrogen plot shows this to be the condition, even if absolute figures are in error from year to year or season to season. We are at a complete loss as to whether this nitrogen arose by release from the soil complex by chemical, or biological action (or both), or was a photochemical fixation.

We do know in our case, however, that drying off of the soil, fallowing, and increased soil temperatures, increased the available nitrogen to a certain extent. By analysis it was found that the nitrogen applied to the soil was either taken up, fixed, or otherwise lost, within a period of three and one half to four months from time of application.

The data from the single-application treatment indicate that the Makiki soil nitrogen release is too slow, and not sufficient in total amount to maintain ideally the plant at any time under the growing conditions here. When nitrogen is supplied in one early application, that which gets into the plant plus that which later comes from the soil is not sufficient to carry a crop over 16 months of active growth. These facts point to a tie-up in the soil-to-plant transfer of nitrogen, either chemically or biologically, *which inevitably means losses where excess nitrogen is applied at one time and not graduated to the plant's size and age.*

The weather conditions available for growth of sugar cane have been covered in the various papers by Das, Clements, and others. It is mentioned here because it appears that below certain limits of temperature any large responses due to nitrogen differentials are lost. When the soil fixation or "loss" factor is considered, it is certain that much of the fertilizer, applied when the plant has not sufficient time to efficiently assimilate all of it during the ideal growth period, will be lost.

In other words we found that nitrogen should not be applied to H 109 cane grown at Makiki under the conditions of this test, just before the onset of seasonal conditions which are expected to depress growth.

Taking into consideration the normal starting times for crops in Hawaii, we are faced with the fact that the temperature curves and the ideal growth curves for cane are bound to collide sometime within the first nine months of the crop life to the disadvantage of the growth. It becomes readily apparent that a compromise fertilization schedule must be adopted, so as to apply the fertilizer at the proper age in the proposed crop life (which includes the maturation period) to take advantage of the better growth periods. By this means it will be possible to bring the largest part of the stalk to a state of ripeness (or vegetative dormancy as we now visualize it) through an induced nitrogen shortage and age.

For economy's sake in extremely short crops one application seems ideal, whereas for long crops two or three applications are advisable. *The important problems involved in fertilization are really the problems associated with the avoidance of excess nitrogen fertilization for the weather conditions under which the crop is expected to grow, rather than the problems dealing with specific nitrogen deficiencies.* Plantations, as a rule, do not complain of juices from slightly nitrogen-deficient fields, though cane tonnages may be depressed somewhat at times. In the race for greater tonnages of cane, quality of juices are sacrificed *too often* for quantity.

Plant tissues from any anatomical part, although at times apparently suitable, cannot always be used as satisfactory indices for fertilization because the nitrogen percentage so determined is only indicative of the plant content and does not indicate what the soil may release under the variable, seasonal, light, moisture and temperature conditions during the ensuing life of the crop. Drought apparently causes fairly large increases in available nitrogen in the soil and, when water becomes available, part of this soil supply is taken up by the plant for further growth, causing a resulting upset in plant percentages not only of nitrogen but also of sugar. Thus under irrigated conditions soils will tend to follow a smoother nitrogen-content curve than they will under unirrigated conditions.

On unirrigated plantations soil nitrogen should be watched at the same time tissue content is, or excesses may be applied when they are not needed and are not assimilable by the plant due to too low soil moisture. Later, when water does become available, heavy growth ensues and juices are depressed in quality.

As will be brought out in a later paper dealing with the effects on three different varieties of cane, growth habits primarily of genetic origin rather than of treatment heavily influence nitrogen fertilization practices on different varieties; this points to the necessity for study of water and nutrient requirements for each individual variety. The applications to a new variety are usually those applied to an old familiar standby even though the two may bear little relationship to each other genetically or otherwise, except that they are sugar canes.

As our new cane varieties bring wild, vigorous, new strains into the picture, with relatively high response to season and weather stimuli, as well as efficient use of nutrients to promote vegetative responses, more and more will we have to avoid excesses of nutrients of all sorts, so as to be able to avoid the peak seasonal growth and respiration effects on stored sugars and sugar storage. These points will be brought out in a later paper.

What we are emphasizing here is that the sucrose storage rate is inversely related to growth and respiration rates regardless of what variety, location, or treatment we consider.

The plantation manager's problem is to adapt his fertilizer policy to give the best compromise between the three rates as established by the weather, environment, and variety. If he were to fertilize to get optimum yields in average years, when normal weather conditions act as a check to excessive growth, and then should get abnormal growing temperatures, the juice quality would be affected.

So far no satisfactory method of weather prediction is available for two-year periods, so actually the plantation manager has little recourse but to apply his normal experienced optimum fertilizer application and trust for the best. The timing of the applications allows him some control over the type of vegetative growth and the length of life of his crop, but this is also largely at the mercy of the weather.

Midway Islands

By Fred C. Hadden

Very near the center of the North Pacific Ocean there is a coral atoll or circular coral reef in which there are two small islands. This reef and the two enclosed islands are called Midway Islands, or simply "Midway". They were discovered in 1859 by Captain N. C. Brooks who took possession of them for the United States of America.

Midway—The Middle

If one will look at a map, he will find that Midway is in the middle of the North Pacific Ocean. Not only is it in the almost exact center of the North Pacific Ocean, but it is also halfway around the world from Greenwich, at which point our time begins. Midway is about 300 miles north, and 900 miles west of Honolulu. It is not in the tropics, nor is it a "South Sea Island." Distances from Midway to other parts of the world are approximately as follows:

Midway To:

Johnston Island	S.E.	1,000 miles	San Francisco	E.N.E.	3,200 miles
Honolulu	S.E.	1,300 "	New Guinea	W.S.W.	3,400 "
Wake	S.W.	1,200 "	Alaska	N.N.E.	2,000 "
Kamchatka	N.W.	2,000 "	Shanghai	W.	3,600 "
Canton Island	S.	2,200 "	Samoa	S.	2,800 "
Aleutian Islands	N.	1,600 "	Australia	S.W.	3,800 "
			Japan	N.W.	2,600 "

Sand Island, the larger of the two islands in the south side of the lagoon, was colonized in 1902 by the Commercial Pacific Cable Company. At that time there was no vegetation on Sand Island—it was nothing but a blinding glare of white, shifting sand, inhabited only by several million sea birds. However, the other island in the lagoon, now called Eastern Island, was even at that time fairly well covered by Scaevola, wild grasses, and Boerhavia. The roots of Boerhavia furnished castaways on Midway their only vegetable food, and it very possibly prevented death from scurvy.

Many passengers passing through Midway ask: "How old is Midway?" Geologically speaking, the atoll is probably very old, possibly 100,000 years or more —perhaps millions of years old. There is no way at present to determine how old it is. However, the atoll is a coral and sand platform resting upon what must be a very old volcanic mountain top, with the living and dead coral exposed in a ring at the outer edge of the reef in a somewhat circular barrier which breaks the force of the giant waves from the open sea. Waves inside the lagoon are rarely more than 2 or 3 feet high. However, great waves from 20 to 30 feet high often break on the outer reef during winter months in stormy weather. As they break on the reef the spray sometimes flies upwards for from 50 to 100 feet.

Geological Formation

The reef was very likely formed as follows: A million years ago, or more, lava began to erupt from a weak place in the earth's crust on the bottom of the ocean. As more and more lava poured out it built up a great volcanic cone that may have emerged from the sea to a height of several hundred or even several thousand feet above sea level. From sea level to the bottom of the ocean at this point is about 12,000 feet or well over 2 miles. The small part of this volcanic mountain which was exposed above the sea was worn down by the action of waves, or perhaps by the great ice cap that may have moved this far south during the ice age (possibly 1,000,000 years ago). The land was worn down to, or even a little below, sea level at that time. Eventually the ice cap melted, slowly raising the sea level as the ice disappeared. Then both coral-building animals and plants began to grow on the submerged mountain top, until the lava was buried under hundreds of feet of coral rock. We do not know how far down we would have to drill before the lava rock would be reached. At first the coral probably formed more or less uniformly on the flat-topped lava rock. Later it grew more rapidly on the outer edges of the reef, and thus built up a ring of coral. Then the sea subsided a little so that this outer ring of coral was exposed above the surface of the sea, as it is now, leaving an irregular shallow lagoon inside the reef. The deepest water inside the lagoon is only 60 feet, and the average depth is about 8 feet.

Then the action of waves and wind built up the small island of broken coral, shells and sand which is now called Eastern Island. Later on under somewhat different conditions another island was formed of sand only. This is now called Sand Island and has been colonized by the Cable Company and by Pan American Airways.

Eastern Island, being the older island, has had vegetation on it for hundreds of years. Because the island is constructed of coarse pieces of broken-up coral, shells, gravel, and coarse sand, it is very porous, and the water there is quite brackish, containing much salt from mixture with sea water. However, donkeys that were turned loose on Eastern Island managed to survive by going down to the edge of the beach, where they pawed holes in the sand and drank the water which trickled out into these holes. This is a mixture of rain water and a little sea water, brackish, but just barely sweet enough to support life.

In 1902 when the Cable Company first started operations at Midway, Sand Island was a level waste of wind-blown, glaring sand, with only a very few bunches of grass, one or two small Scaevola bushes, and a few Boerhavia vines growing in widely scattered locations. There was one large sand dune about 30 feet high where the Cable Company light is now situated, and the rest of the island was only a few feet above sea level. The Cable Company planted San Francisco grass, *Ammophila arenaria,* and hundreds of ironwood trees around their compound. After a few years the trees were large enough to protect the rest of the north end of the Island from the terrific wind storms which come intermittently throughout the winter months. This allowed the San Francisco grass, Scaevola, and Boerhavia to spread rapidly, so that 20 years later sand dunes 10 feet high had formed around the Island. Every place a Scaevola bush had got a good start it formed a dune as the sand accumulated in and around it. As the sand filled in the bush kept

growing, and more sand was collected among the branches, so that now some of the dunes are 30 to 35 feet high, with just the tops of the bushes appearing above the sand.

Because the sand is finer on Sand Island, it holds rain water better than Eastern Island, consequently the ground water on Sand Island is only slightly brackish. This almost-fresh water is held up in the Island by pressure from the sea water, which is denser or heavier. It has only a slightly salty taste, but does have a rotten egg odor—due to the hydrogen sulphide which comes from the millions of eggs that broke or rotted on the Island, and also from bird guano, and the remains of the millions of birds that have died there. Many thousands of birds die every year, either from disease or from starvation. Flies breed in these dead birds, and at various times of the year they are very bothersome. Small white crabs, that live in holes in the sand all over the Island, also eat the dead birds.

Shipwrecks at Midway

For some strange reason Midway has acted as a magnet, attracting ships to it and then wrecking them. More ships have been wrecked on Midway than on any other leeward island of the Hawaiian group.

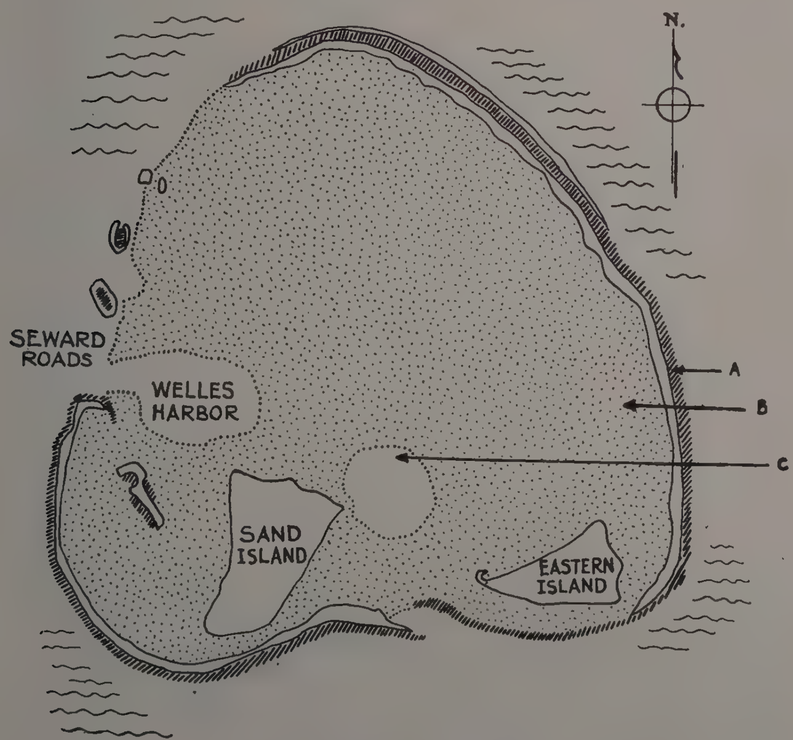


Fig. 1. Map of Midway Islands prior to improvements: A—coral reef, mostly submerged; B—shallow water in lagoon; C—deep water in lagoon.

The "General Siegel" with Captain Jacobsen in charge was wrecked at Midway during a storm on November 16, 1886. Immediately many weird things began to happen. First one of the sailors named Larkin had his hand blown off while fishing with dynamite, and a few days later died complaining of great pain in his stomach. Another sailor named Brown accused the captain of poisoning Larkin. Then Brown and Captain Jacobsen went over to Eastern Island, but the captain returned to Sand Island alone, stating that Brown had accidentally killed himself.

Jorgensen, another sailor, then went with the captain and a German boy to Eastern Island and the captain showed them where he had buried Brown. The captain stood by indifferently while they dug up Brown's body—and found a bullet hole in the back of his head!

Several days later the captain and Jorgensen went again to Eastern Island and Jorgensen returned alone to Sand Island, saying the captain had disappeared! The captain was never seen again.

Jorgensen's shipmates outfitted a boat which had drifted from the wreck of the "Dunnottar Castle" on Kure or Ocean Island, 60 miles northwest of Midway, and sailed for the Marshall Islands, leaving Jorgensen marooned and alone on Midway. They had accused him of killing the captain and were afraid to take him with them. He remained alone on Midway for nearly a year, until the "Wandering Minstrel" arrived.

Fig. 2. Captain Walker's house on Sand Island (1888).

On February 8, 1888, the "Wandering Minstrel," commanded by Captain F. D. Walker was wrecked in Welles Harbor—all hands including Captain Walker's wife and three sons got to shore safely in small boats.

On October 13, 1888 (Saturday), John Cameron, Adolph Jorgensen, and a Chinese boy named Moses, left Midway in a small boat. On November 25, 1888, after a voyage of 43 days, they landed at Mille Island, 1540 miles from Midway.

George C. Munro has very kindly loaned me the photographs taken at Midway in 1891 by one of Mr. Walker's sons. These pictures show the house occupied by the Walker family after they were shipwrecked at Midway in 1888. In the photograph showing the Scaevola bushes forming sand dunes to the left of Walker's home may be seen some of the huts occupied by the other castaways. They barely show at the extreme left. Another picture shows the huts of the men on Eastern Island where there was more vegetation.

According to Mr. Munro there were no goonies, boobies, or bosun birds on Sand Island at this time (1891), and only one or two small colonies of sooty terns were nesting at the other end of the Island. Apparently all the goonies, bosun birds, and moaning birds had been eaten by the castaways!

Fig. 3. Castaways' huts—above, on Eastern Island; below, on Sand Island (1888).

The sloop "Helene" was wrecked on Sand Island during a northwest storm (date unknown); she brought to Midway the crew of the bark "Kellogg" which had been wrecked on Dowsett Reef.

Saved by a Toe:

About two o'clock one morning in December, 1903, the schooner "Julia Whalem" struck the north rim of the reef "bow on." The life boat was lowered and the crew scrambled into it. They discovered they had no oars, so climbed back aboard the schooner to look for some but none could be found. The only thing they could find to use as oars were brooms, and these were used to row around the reef into Welles Harbor, and to shore at the Cable Company dock. Not only were there no oars but the boat started to fill with water and sink. They then discovered that there was no plug for the drain hole in the bottom of the boat. Happily they found that one of the "kanaka" sailors had a toe big enough to satisfactorily plug the hole and this saved the day. The ship broke up and sank two hours after striking the reef.

The Anchor on the Southeast Reef:

On Christmas Eve, 1906, the bark "Carlton" went aground, "bow on" on the southeast reef. Apparently they threw the anchor overboard in order to hold the ship on the reef and keep it from sliding off backwards and sinking in deep water. The anchor is still there and shows plainly in calm weather. The captain and crew took to the boats, and rowed around the reef and into Welles Harbor to the Cable Company dock. Three trips were made, each time salvaging as much cargo as they could. A few days later a southwest storm came up and on New Year's Day the ship broke in two and was demolished.

According to A. R. Tinker, a Cable Company employee, at that time there were no ironwood trees on the Island, and very little plant life of any kind, so the wreck could be plainly seen from the second floor of their quarters at the Cable Company. The ironwood trees were planted in 1907. In 1940, 33 years later, the trees were from 60 to 70 feet high.

The Commercial Pacific Cable Company

In order to maintain and operate a submarine cable across the Pacific it was necessary to establish a relay station at Midway.

In 1902 the Cable Company landed on Midway and started the construction of their compound on Sand Island. All the material and equipment had to be brought ashore in whaleboats and lighters. It was a long haul from Seward Roads or Welles Harbor in to shore, or in through the treacherous S-shaped, small-boat channel in the south rim of the atoll. In those days everything had to be moved by man power—it was really tough.

However, they did build substantial steel and concrete buildings, water towers, windmills, a very large concrete cistern for fresh water storage, a steam ice-plant, a dock, and everything needed for operating the cable and for the comfort of the men stationed there.

Four times a year, for 15 years, 150 tons of soil were brought to Midway, and after that 2½ tons were brought in on each supply ship. It is estimated that over 9,000 tons of soil were imported for use in the 3-acre vegetable garden, and to scatter around on the sand for lawns to keep the sand from blowing out from under and around the buildings.

San Francisco grass and hundreds of ironwood trees were planted for protection from the winter storms. They now have a little paradise of their own, with ducks, chickens, turkeys, pigs and cows. The vegetable garden supplies them with fresh vegetables after the supply brought in once every three months runs out. Most of the men stay for a year or two—some stay longer.

Only the chief and his assistant could have their wives on Midway. Often for many months at a time there was only one woman on the Islands, at other times there were no women there. The inhabitants led a calm and peaceful life, disturbed only by a slight flurry when the supply ship arrived.

Pan American Airways

In 1935 the first expedition of the P.A.A. arrived at Midway and began to "dig in." They too had all the difficulties of unloading equipment and building materials from the ship on to lighters which had to be towed to shore, then unloaded

Fig. 4. Pan American Airways' quarters. Trees shown in top photograph are one year older than those in the lower picture.

and the materials reloaded on to sleds which were hauled up to position by a Diesel caterpillar. That "cat" has moved many thousands of tons of cargo—all the building material, and thousands of drums of gasoline each weighing about 450 pounds. It is still running.

The P.A.A. set up quarters for the men, a fine hotel for passengers, a power plant consisting of 3 large Diesel motors and generators, 2 windmills with tower tanks, and twenty 4,000-gallon steel tanks for the storage of rain water caught on the roofs of the buildings.

Thus a modern little town was set up within 7 or 8 months' time, with electricity, running hot and cold water (sun heaters), modern plumbing and nearly all the comforts of home.

Instead of waiting 3 months to hear from home, the Cable Company personnel received mail once a week—and how they complained if the plane was delayed a few days by weather. It is amazing how much cargo, besides mail and passengers, is brought to the Island on the planes.

On nearly every ship hundreds of pounds of fresh milk and cream, eggs, vegetables, fruit, and local express are unloaded at Midway and Wake, and even Guam. Once a week the plane also brings a new "movie" for our entertainment. Two dozen potted palms, each weighing 20 to 30 pounds, were brought here by air.

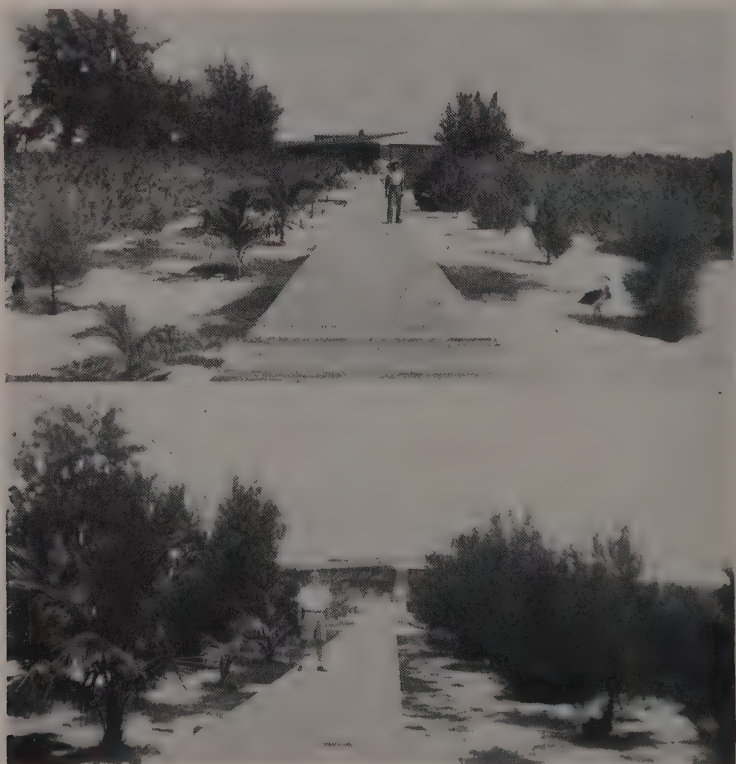


Fig. 5. Ironwood trees on Sand Island showing one year's growth.

Grass and ornamental plants supplied by the Hawaiian Sugar Planters' Association have been planted around the hotel, as well as trees for protection from strong winter winds. Ironwood trees planted 4 years ago are now from 25 to 30 feet high.

Only the "old-timers" who saw the place as it was at first can now appreciate all the work that has been done here.

Entomological Inspection

On November 24, 1936, the Philippine Clipper, a Martin flying boat, left Honolulu at 7:15 a.m. with the writer aboard. We had perfect flying weather, the visibility was unlimited, and a fine view of Kauai and most of the other islands was obtained on the way to Midway. It was about 6:30 p.m. when Midway was sighted, and it was completely dark when we landed by the aid of night landing lights.

Mr. Clark, the hotel manager, showed me to my room in the radiomen's quarters. It is small, about 8x10 feet, but cozy and comfortable, with a good bed, electric lights and heaters, chair, dresser and wardrobe. Later a small laboratory was made for me on the front screened porch of the quarters.

The next morning we were all up again at 4:30 a.m., long before daylight, in order to prepare the plane for the flight to Wake. The baggage and food were taken to the dock in "banana wagons" or station trucks, then loaded into the launch and taken to the barge, transferred to the barge and then stowed away in the proper places on the plane so as to maintain the "C.G.", or center of gravity, at the proper spot in the plane. At this time the plane was given its second entomological pre-flight inspection in order to find the insects killed by the spray treatment given the plane upon arrival. Dangerous plant pests and mosquitoes are sometimes found dead at this time. The plane was also carefully searched for insects upon arrival. From 15 to 20 insects, consisting of 5 or 6 species, are frequently found during this inspection. In one case over 1,000 insects were found on the plane; very rarely are no insects found. About 200 species have been found on the planes arriving at Midway. Most of them came from Honolulu, Wake, Guam, Manila or Hong Kong. Many of them are species not found at Midway, in Honolulu, or on continental United States.

One important insect pest that is prevented from reaching Honolulu and the U.S. mainland from the Orient by the spraying of the planes at Midway is the Anopheles mosquito, the carrier of malaria. If this mosquito and malaria should become established in the Hawaiian Islands, human efficiency would be cut down and hundreds of thousands of dollars of damage would result. There would even be a number of deaths due to malaria, and certainly the present high level of health would be lowered.

Sugar cane pests as well as other plant pests, such as beetles, bugs, moths, grasshoppers, flies, crickets, earwigs, etc., arrive alive at Midway on the planes from the west and are prevented from reaching Honolulu alive by the inspection and spray treatment given the planes at Midway.

All specimens found on the planes at Midway are collected and sent to the entomological museum of the Experiment Station of the Hawaiian Sugar Planters'

Association in Honolulu where they are identified and preserved. They now total thousands of insects.

Similar work is also being done at Canton Island by Richard R. Danner, in order to prevent the introduction of destructive pests from New Caledonia and New Zealand into Hawaii and the U. S. mainland.

Gardening at Midway

Mr. Steadman was the gardener at Midway for Pan American Airways in 1936. He had planted quite a number of ironwood trees, San Francisco grass, and various shrubs, and had started the lawn in front of the hotel, also a vegetable garden. He did very good work considering the difficulties he was up against. Mr. Steadman had fallen down in so many moaning-bird holes that he had developed a chronic limp and always carried a cane. Upon certain exciting occasions this limp would miraculously disappear, and although rather stout he could move with astonishing agility.

Fig. 6. Three-year-old trees on Sand Island. Top—kamani; bottom—ironwoods.

In May or June, 1937, Mr. Steadman's assignment of a year at Midway was ended and he left for the States, and no one was left to care for the gardens and lawns. It was the dry season and everything began to die from lack of water. So the writer, being an amateur gardener and lover of flowers and trees, took over and a Chamorro boy was designated as his assistant. It took all of the boy's time pulling weeds, digging holes for planting and cultivating, and in filling the holes around the corners of buildings where the wind had blown the sand away. Three times that first winter the wind blew the sand out from under, and alongside, all the buildings, especially at the corners where it left holes 3 to 4 feet deep and even undercut the foundations of the buildings so that they rocked from side to side. Many tons of sand were moved in filling these holes. No sooner would grass be planted than another storm would come along and blow the grass and sand away again—it was most discouraging.

It was an unusually dry summer, and the lawns and plants had to be watered daily, one area one day, another area the next day. The volume and pressure of water available was inadequate, and in order to supply the plants with enough water to keep them alive, it took from 12 to 14 hours a day. Only two sprinklers could be used at a time, or one sprinkler and an open hose. The sprinklers had to be changed every half hour, all day long. New plants grown by the Experiment Station, H.S.P.A., were arriving on each plane from Honolulu and had to be potted. This kept me busy from daylight to dark and lasted six months, then another Chamorro boy was added to the gardening department, and things eased up a bit when the winter rains came.

People in the States seem to think that Midway is a South Sea tropical paradise—it is far from it. It is decidedly temperate in climate, cold in the winter and pleasantly warm in the summer. Temperatures range from 50 to 85 degrees F. We never get frost and very rarely a little early morning fog. It rains and blows in the winter time; some of the storms are terrific with gusty winds up to 70 or 80 miles an hour. The summers are almost perfect, warm and calm and not too humid—it is always cool in the shade. We get 50 to 60 inches of rain a year, but the winds and sun dry out the sand to a depth of a foot in a few days. Shallow-rooted plants such as grasses and vegetables suffer from drought in the summer when the

Fig. 7. Pan American Airways' supply ship "Tradewind," and their launch.

rains are not frequent enough. May, June, July, September, October, November, and December are often very dry; sometimes fairly heavy showers occur in August.

Tropical Hawaiian plants grow well here in the summer. In the winter, from January through April, the strong cold winds "burn" the leaves off hibiscus, croton, milo, kamani, vitex and oleander. The leaves and flowers of periwinkles are reduced to one third their normal size, as also are the leaves of Tournefortia and Scaevola. Most of the old leaves drop off, leaving the long bare branches exposed to view. Coconuts are often killed outright by the cold winds; they do well where protected by other trees.

Originally there was no soil on the Island, and consequently it was necessary to make the small amount of soil we had go as far as possible. Only a total of about 30 tons of soil has been available for use in the P.A.A. gardens.

The sand here is coral and shell particles ground up to a fine size by the action of the waves and winds. It is almost pure limestone or calcium carbonate, completely lacking in all plant foods except calcium, and of this there is far too much. In addition, making the growing of plants even more difficult, the only water available in the large quantities needed for lawns and trees is the brackish ground water, which contains just a little too much salt for most plants.

The droppings of millions of birds have added a small amount of phosphate and other minerals in minute quantities to the sand and ground water. There are no deposits of guano here as there are on many South Sea Islands, or as there are on Laysan Island where conditions were favorable for its accumulation over a period of hundreds of years.

Here, what guano is deposited every year is either blown away by winds, or washed away by rains. Except for phosphates, the main elements of plant growth such as nitrogen, iron and potassium are present in such minute quantities that it is amazing that anything can grow at all.

At first it was thought that it would be possible to grow plants here by simply adding large quantities of humus or vegetable matter to the sand. Such an attempt was a complete failure. Apparently the lime sand soon dissolves the humus which is then washed away by rains beyond reach of roots and, consequently, nothing is left to sustain plant life. Most plants failed to grow in a mixture of one-half sand and one-half humus, or in two-thirds sand and one-third humus, even though in both cases small amounts of chemical fertilizers were also added regularly. It was quite a problem, Apparently what was needed is that which is entirely lacking—kaolin or clay. Most soils are composed largely of this material which also contains many of the plant foods, such as iron and potassium.

More than 200 species of plants have been tried out in our "sand pile," in order to determine which will grow in the pure sand, with brackish water, or in sand with a little soil added. It was soon discovered that quite a few plants would grow in the sand even though only a small amount of soil, from Honolulu, was added, providing the soil was very thoroughly and intimately mixed with the sand. However, most of the plants required fresh water, for brackish water soon killed them if given too freely. Small amounts of a complete fertilizer had to be added frequently, every 2 or 3 weeks, in order to obtain satisfactory growth.

A mixture of 1 part soil to 3 or 4 parts of sand was found to be satisfactory for most ornamentals, grass and vegetables. However, about one inch of soil should be added on top of each plot, and thoroughly worked in by spading or hoeing to a depth of 8 to 10 inches every year if the garden is to be kept productive. This can be done at anytime of the year between harvesting and planting.

In order to conserve soil, plots were made for vegetables and flowers, in rows 50 feet long, 3 feet wide and 3 feet apart. Soil was placed on the sand in the rows to a depth of 2 or 3 inches and worked in as deeply as possible. This made a slightly raised bed, with sand walks between the beds. The rows should run north and south, in order for the sunlight to reach both sides of the plants in the plots. Each plot was planted in two rows of vegetables about 6 inches from the edge of the plot. A row of radishes was often planted between rows of slow-growing plants, down the middle of the plot. These were harvested before the other plants had become large enough to shade the radishes.

The following vegetables and flowering plants seem to be well adapted to successful growth under these conditions:

Fig. 8. Pan American Airways' vegetable garden.

Vegetables

Radish (long red)	Chinese cabbage (Wong Bok)
Lettuce (Los Angeles)	Head cabbage
Broccoli	Swiss chard
Beets	Tomato (Marglobe)
Carrots	Eggplant
Turnips	Casaba melon
Sweet potato	Persian melon
Kale (Scotch curled)	Cantaloupe or muskmelon
Kohlrabi	Papaya (if protected from winds)
Rutabaga	

Flowering Plants

Periwinkles	Sunflower
Various-leaved spurge	Nasturtium
Carnation	Gaillardia
Geranium	Sweet alyssum
Chrysanthemum	Stocks
Gladiolus	Pot marigold
Alfalfa	Rose
Tithonia	Begonia
Coxcomb	Poinsettia
French marigold	Oleander
Phlox	

The flowers must be watered with fresh water only, or depend upon rainfall, except gaillardia and periwinkles which may be watered occasionally with brackish ground water. The vegetables should rarely be watered with brackish water. It should be remembered that when brackish water is used there is an accumulation of salt formed, which soon becomes so strong that it will kill anything.

Many kinds of trees and shrubs have been tried, and the following species are the only ones that have been grown successfully in a mixture of sand and soil, one part soil to 3 or 4 parts of sand.

Ironwood	West Indian kou
Kamani	Bengal banyan
Sea grape	Pandanus
Button bush	Coconut (when protected from winds)
Oleander	Palms (date palm type)
Tree heliotrope	

These 11 species may also grow well in the sand without soil or fertilizer, especially the first 5 species, as also do coconut, pandanus, vitex and spider lily.

The following species must have soil mixed in with the sand in order to grow well, and most of them require fresh water.

Tamarix	Sanseveria
Mulberry	*Coprosma baueri*
Banana (if protected from winds)	Acalypha
Baobab	Dieffenbachia
Brassaia	Mock orange
Plumeria	Hibiscus
Flame tree	Bougainvillea
Croton	Poinsettia
Vitex	Panax
Dracaena	Ti

Brassaia, plumeria, croton, vitex, coprosma, panax, and bougainvillea will tolerate small amounts of brackish water. Fresh water should be given to them when available.

Fertilizers:

At first a complete fertilizer was used. This is a mixture of various nitrates and phosphates made by chemical fertilizer companies, and may be called "lawn," "fruit tree," or "vegetable fertilizer." "Gaviota," a mixture made in California, was found to be fairly satisfactory when used in small quantities at frequent intervals.

However, these commercial fertilizers consist mostly of ammonium sulfate and phosphates. If applied too freely it burns the plants badly under Midway conditions. Also some plants apparently showed that they were not getting sufficient iron and potassium. For this reason a new mixture has been tried, and has been found to be more satisfactory. It is:

Nitrate of potash	30%	
Sulfate of ammonia	20%	
Dried blood	10%	(may be omitted)
Sulfate of potash	10%	
Superphosphate	20%	
Iron sulphate	10%	(may be increased to 20%)

Peat humus can be used to advantage on Midway when mixing soil and sand, especially for potted plants such as dracaena, palm, ti, croton, bowstring hemp,

Fig. 9. Pan American Airways' garden showing cantaloupe, cabbage, and turnips.

hibiscus, gladiolus, carnation, zinnia, marigold and other flowering plants. In this case a mixture is made of 1 part soil, 1 to 2 parts sand, and 1 part peat humus. Into 100 pounds of this mixture about 1 pound of the foregoing formula should be thoroughly worked. It should then be wet down and mixed again and allowed to stand for a month or more before using, occasionally working it over again with a spade or hoe.

The peat humus should always be thoroughly soaked in fresh water for at least 24 hours before being used.

Ammonium sulfate should not be used under Midway conditions for just a little too much will kill plants outright.

The only grass that has proved satisfactory at Midway is Bermuda grass. Other species die out in the summer time during warm dry weather. Apparently they cannot stand the combination of so much lime and brackish water, the only water available in large quantities for lawns.

Garden pests:

There are only about 50 species of insects found on Midway. In general they are conspicuous by their absence, with the exception of two species of flies, the house fly and a carrion fly, and ants, particularly *Pheidole megacephala.*

Nearly all of the insects on Midway have been brought here in soil or on growing, potted plants from Honolulu. One bad moth pest, *Prodenia litura,* probably came here from Wake. It is not found in Hawaii.

Our most destructive pest is not an insect at all, but is a bird, the Laysan "finch," introduced many years ago from Laysan Island. This fearless little rascal does more damage to plants on the Island than all other pests combined. It should be outlawed and destroyed at every opportunity.

Mosquitoes were bad when we first arrived here. Many wells and innumerable cans, bottles and other breeding places had to be destroyed before they were controlled. This work has been so successful that many of the new residents on the Island have never even seen nor heard a mosquito since arriving here. The only species present is *Culex quinquefasciatus.* It will be necessary to continue the program of destroying all breeding places if the mosquitoes are to be kept down. All tanks, wells or other water containers must be kept screened, or covered so tightly that no mosquitoes can get into them.

Flies become very numerous and bothersome and a real nuisance in the late summer, especially during July, August, and September. They breed in the dead birds and possibly in bird dung when conditions are favorable. For this reason all dead birds, old eggs and other garbage should be burned or taken far out to sea and dumped on the lee side of the atoll, where it cannot drift back to shore.

Pests that feed on plants are represented by several species of caterpillars, armyworms, cut worms, and loopers. Aphids sometimes breed in large numbers, and scale insects and mealy bugs become numerous enough to be destructive in the summer. Cockroaches also breed rapidly in the summer, especially in and around kitchens.

So far we have been very lucky. We have no scorpions, centipedes or termites on the Island, or if we have they are so rare that they have not been found.

We also have no rats, and it is hoped that great care will be taken, when ships are unloading here, to prevent rats from coming ashore.

The Sea Birds on Midway

When approaching Midway by steamer a strange sight greets the eyes. It appears as if the air over the Island is filled with a vast swarm of giant bees. Upon closer view one soon realizes that there are countless thousands of birds milling around in the air, and their screaming is almost deafening.

In 1902, before the Cable Company arrived at Midway, W. A. Bryan visited the Island. Poachers had already done enormous damage. Thousands of bodies of dead birds lacking tails and wings were thickly strewn over both Sand and Eastern Islands. Apparently they had been ruthlessly slaughtered for their feathers for millinery purposes. Mr. Bryan reported this foul deed to the proper officials in Washington and thus started the campaign to make the leeward islands of the Hawaiian group a bird reservation.

In 1905 a party of poachers was found killing the birds on Lisiansky Island. They were arrested by officers of the U.S. Revenue Cutter *Thetis* and taken to Honolulu. They had killed over 300,000 birds.

Savage Slaughter:

Homer R. Dill and Wm. Alanson Bryan visited Laysan Island from April 24 to June 5, 1911. This is what we find in their *Report of An Expedition to Laysan Island in 1911,* U.S.D.A. Biological Survey Bulletin 42.

In 1909 a party of feather hunters had been on Laysan Island and killed more than 200,000 birds, mostly albatrosses.

Captain W. V. E. Jacobs of the Revenue Cutter *Thetis* arrested 23 poachers and confiscated their booty consisting of the plumage of more than a quarter-million birds.

According to a government official who was in Honolulu at that time these poachers were never punished.

The visitors' first impression was that the poachers had stripped the place of bird life. An area of over 300 acres on each side of the buildings was utterly devoid of birds, and apparently all the goonies in this area had also been killed.

On every side bones were bleaching in the sun showing where the poachers had piled the bodies of the birds after stripping them of wings and feathers. In the old guano shed were the remains of thousands of wings placed there for curing, but never shipped as the marauders were interrupted in their work. In a dry cistern hundreds of live birds had been herded and left to slowly die of starvation in order to reduce the amount of fatty tissue lying next to the skin, and thus making the job of skinning and cleaning the skins easier. Wings had been cut from living birds, and the birds left to slowly bleed to death. Killing clubs, nets and other implements used by the marauders were lying all about. Hundreds of boxes to be used in shipping the bird skins were packed in an old building. It was

evident that they intended to carry on their slaughter as long as the birds lasted. Cages were found in which they had been placing the smaller birds alive.

It is the writer's opinion that at one time goonies were numerous on Wake Island. The wandering albatross has been reported as nesting there. But if they were there, they have since been completely killed off. Three years ago there were 3 black goonies on Wake, this year there were 7 or 8. Apparently they are beginning to move back in again since they are protected by the Pan American personnel on the Island.

Within the past two years, two ships have been wrecked in the leeward islands of the Hawaiian group. One at Kure or Ocean Island, and one at Pearl and Hermes Reef. No one seems to know anything about them. What were these two ships doing in Hawaiian waters, and why were they not reported?

Without doubt other islands, such as Kure, which is rarely visited, have been invaded by poachers, and the birds destroyed for their feathers.

We sincerely hope that in the future it will be possible to keep a closer watch on the uninhabited islands, and if visitors are seen on them and found molesting the bird life, they should be arrested and punished.

Sooty Tern:

Most numerous and noisiest of all the birds on Midway are the sooty terns. The first flock appears some evening in March or April, usually about sundown. Their cries fill the air long before they can be seen. They come in and fly around and around in a great whirlwind-like formation, but do not come down to the ground for a month or more. Sometimes they go away for a few weeks and then return again. All night long they circle and scream over the Island. Early the next morning they again go out to sea for fish. In the evening they are back again. Day after day they repeat this performance, returning a little earlier every afternoon until finally after five or six weeks, they continue to fly over the Island both day and night. Then they begin to light on the ground, at first only for a few moments, and finally after another week they settle down more or less permanently, rising only when disturbed. However, they keep up their incessant screaming long after the egg-laying period has passed.

Fig. 10. The sooty tern.

In the meantime, about two weeks after the first flock has arrived, another one appears. Then for about three months, more and more flocks appear, until by June all the flocks are in and the first to arrive has settled and is incubating its eggs. There must be nearly 600,000 terns on the Island when they are all here. Imagine—over half a million birds on a small Island that you can walk around in an hour and a half! And these are not even half the number of birds that are on Midway in May and June.

What kind of a bird is this noisy, powerful flyer, and what does he eat? The sooty tern is a small, graceful, perfectly streamlined, black-and-white bird, with partly webbed feet and two long tail feathers. The breast and neck are snow-white, and the back and top of the head are sooty black. The beak is long, straight and sharply pointed. It is about the size of a dove.

It lays a very large egg (for its size) on the bare sand, sometimes in a slight depression, and the egg hatches in about a month. Both mother and father bird take turns setting on the egg, changing off about once a week. While one bird sets on the egg the other is out fishing, sometimes far at sea. Here in the open sea it catches small fish and squid or cuttle fish; it also catches small minnows inside the lagoon.

The newly hatched bird is covered by one or the other of the parents for about a week; from then on, one of the old birds stands guard near by until it is nearly full-grown. The old birds feed the young one by regurgitating the partially digested fish they have obtained at sea. This species of tern never feeds the young whole fish, but always partly digested material. In about three months the young bird is full-grown and begins to fly down to the edge of the beach or to sea with its parents. At this time it is a speckled, dark gray bird that does not look at all like the adults. A week or two later they all disappear out to sea again, and no one knows where they go. Very likely they stay at sea all the time they are gone, from August to April, and rest now and then on the water.

The first five or six weeks of a young tern's life is fraught with danger. Frigate birds swoop down, grab them without lighting and gobble them down. This doesn't seem to bother the old terns very much for they do nothing about it. One frigate bird was observed to eat eight young terns in one day. But just let a human being try to walk through a colony of nesting terns. What a rumpus they make, and how they apparently swear at you. They are very brave little fellows, and stand right there by their egg or young, facing you without moving, and telling you in no uncertain terms just what they think. Others fly around your head and occasionally peck you with their needle-pointed beaks, sometimes drawing blood. Usually it is just bluff and they don't touch you. Imagine a person standing up and fighting an elephant. And yet we must seem many times larger in proportion, to that valiant sassy little tern that stands up about six inches high on his toes. We hereby elect him the bravest of the brave.

The Fairy Tern:

Less numerous, but one of the favorites on the Island are the beautiful snow-white fairy terns or love birds, with their bright, shiny, jet-black, shoe-button eyes and blue-black pointed beaks. They are a little smaller than the sooty tern, but

Fig. 11. The fairy tern.

friendlier and much quieter. They are curious and often follow you, circling around over your head, chattering in a low deep voice. If you stop and hold out your finger at a level with the top of your head, and stand quietly they often alight on your finger, or on your head.

Instead of laying eggs on the ground they place them on a bare branch, or in the crotch between two or three twigs. They make no attempt at building any kind of a nest at all. It is amazing that the egg can stay in such a position, but it does, and rarely falls off even during high winds.

It is said that when the young hatch, the feet come through the shell first and fasten on to the branch! (This may be taken with a grain of salt.) However they do it, it must be very tricky. They do hold on so tightly that you almost have to pull them in two to get them off that limb.

At first the old birds feed the young by regurgitation, but very soon they are bringing small top minnows in to the babies which they cram down their throats. Adults often bring in two, three, and even four minnows at a time, held crosswise in the beak. Now, how do they catch that second and third fish without losing the first and second one?

Other Terns:

The Hawaiian tern is not so friendly as our little "fairy." It builds a nest in the ironwood trees, or in the Scaevola bushes, where it is hard to find. It is a very dark gray, almost black, bird with a light gray or almost white "bald" spot on top of the head. It makes a very peculiar noise at night.

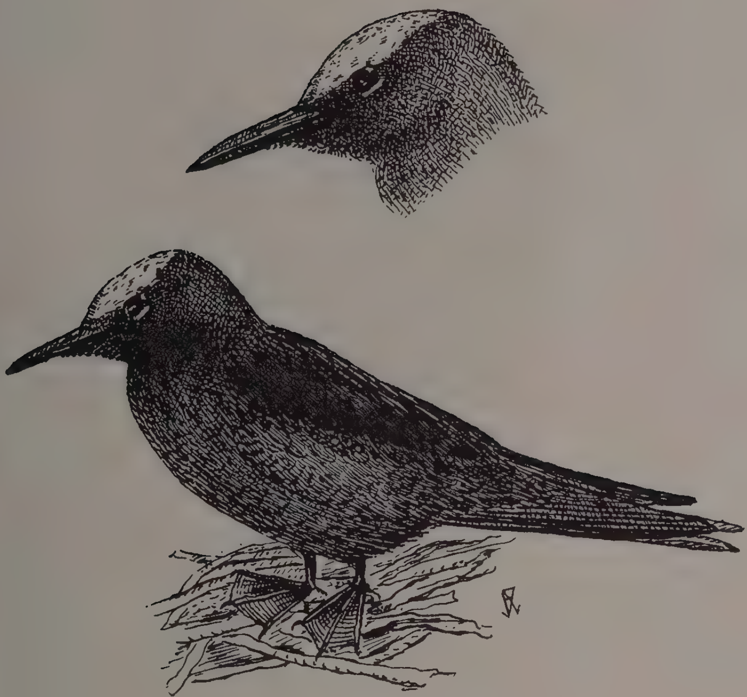


Fig. 12. The Hawaiian tern.

The grayback tern is larger than any of the others, and quite rare here.

This makes a total of four species of terns on the Island. Their numbers are about as follows:

Sooty tern	600,000
Fairy tern	3,000
Hawaiian tern	2,000
Grayback tern	500

Moaning Birds:

Next in number of individuals, and larger in size, are the moaning birds, of which there are several species.

Most numerous are the Bonin petrels, a bird about the size of a pigeon. A conservative estimate of the number of this species on the Island is 500,000. The Bonin petrel is known as the "small moaning bird" on Midway. It has a white breast but otherwise is a dull gray. The beak is turned downwards at the tip into a sharp hook.

This species is not nearly as noisy as his big brother the wedge-tailed shearwater. Both of these species, and many others, are known as Mother Carey's chickens by sailors. In fact the Bonin petrel makes only a small meowing sound, or a kind of a growl, like a kitten does when you try to take a piece of liver away from it.

Sometimes while mating they have a high shrill cry that is very disturbing. Although they are sometimes seen at sea in the daytime, they are really nocturnal, and do not become active until after sunset. At that time they come out of their burrows in the sand, and actually fill the sky with their great numbers, appearing from a distance like a great swarm of bees covering the entire Island. Over a thousand of these birds were counted on one-half acre near the Pan American Airways' Inn.

Bonin petrels are wonderful diggers. They usually get their head or shoulder up against a plant stem in order to get a leverage for digging, and then they make the sand fly. The burrow is usually about six to ten inches below ground, and three to four feet long. They toss the sand out of his hole to a distance from eight to ten feet, using first one foot and then the other. A rabbit couldn't dig a hole any faster than they do.

They begin to lay eggs in December or January, in a nest lined with leaves at the bottom end of the burrow. The egg is almost as large as a hen's egg. They return to the Island early in September and leave in June, so that there are only two months—July and August—when they cannot be found. A small flock may return in August.

Since Bonin petrels dig holes all over the Island, even in low places where the water level is only a foot to eighteen inches below the surface of the sand, many are drowned during heavy rains. After a heavy rain, of three to six inches, the water rises and floods the lower areas of the Island. However, this does not prevent the old bird from returning again and again to dig in the same old place.

The Bulwer's petrel, all gray in color, is a small moaning bird that is rarely seen on Midway. It has a characteristic cry of "Hoomph, Hoomph, Hoomph," in a deep tone.

Wedge-Tailed Shearwater:

Any person taking a walk around Midway in the evening when it begins to get dark, during March or April, is apt to have a most hair-raising experience. Suddenly out of the dark will rise the most blood-curdling howls, yowls, moans and groans. Not only that, but it sounds as if there must be a dozen tomcats tearing each other to pieces, from the wild cat-like shrieks that penetrate the ear, then some woman begins to groan and gasp and moan, as though about to die in the greatest

Fig. 13. Moaning birds: left, head of Bonin petrel; right, head of the wedge-tailed shearwater.

of pain. All of these various ghoulish noises are so heart rending, so horrible, that one must indeed be brave to investigate them. What a horrible experience it must have been for those first sailors who were shipwrecked here many years ago. Certainly they huddled around their fire trembling and shaking when they first heard these wild cries.

However, if you are brave enough to approach the source of these sounds with a flashlight, or even on a bright moonlight night, you will find that all this terrible racket is made by only two or three pairs of birds, only half again as large as the Bonin petrel, and very similar to it.

They are the "big moaning bird" or wedge-tailed shearwater, the big brother of the "small moaning bird."

There is only one bird that can make a more terrible noise, and that is the "devilbird" of Ceylon and India, a small owl that has an even greater volume and repertoire of terrible cries. There are not many animals that can even begin to compete with either of these two birds.

These cries are the love song of the big moaning bird! Its throat swells out like a small balloon as it passionately sings its love song, which can only be appreciated by another moaning bird. They keep up this din for several weeks, then settle down to the business of digging holes, setting on the eggs, and feeding the young.

They dig a much larger hole than the other "moaners"; it is also deeper and longer. Often their burrow is excavated beneath that of a Bonin petrel, and thus may be down in the ground two to three feet. It is about four or five feet in length and eight to ten inches in diameter. Anyone walking across the Island is bound to fall into these burrows many times, and get shoes and socks full of sand as it caves in around one's feet. For this reason the moaning birds are heartily and fluently cursed by the inhabitants of Midway. You suddenly break through sand, that looks solid, and end up with a jolt, which is very funny when you see the other fellow do it.

The gardener at Midway had made a very nice little garden when the moaning birds were away. After the beets, radishes, turnips, lettuce, carrots, etc., had got a good start, the birds moved in. One night he went out to see how the vegetables were doing. The carrots, beets, turnips, radishes, and lettuce were flying in every direction. The moaning birds were home again, and excavating work was fully under way. There were 1,500 moaning birds at work in that little three-fourth-acre plot.

The wedge-tailed shearwater apparently eats mostly squid, but does eat some small fish.

In August another smaller flock of big moaning birds returns to the Island. The egg is almost as large as a hen's egg. One of the amazing things about nearly all sea birds is that they lay such large eggs in proportion to the size of the bird.

The Bosun Birds:

The bosun bird or red-tailed tropic bird is a beautiful white bird with a pink, pearly iridescent or opalescent sheen to the feathers. The beak is a bright red or orange, as are the two very long, thin tail feathers; the feet are black, and

Fig. 14. The bosun bird or red-tailed tropic bird.

webbed. They nest on the ground in the Scaevola bushes around the P.A.A. hotel. They are found on the Island from May through December, and are away on their winter vacation, probably "down south," from January through April.

These are the birds that fly backwards, just for the fun of it! No, not all the time. During the warm weather in May, June, July and August, at 11:00 a.m., they leave the nest and get up into the air and do a kind of aerial acrobatic dance, accompanied by a great deal of loud squawking in a very raucous voice.

They mill around and around in the air, then go into a gliding dive, pull up into a stall and then fly up and backwards, loudly squawking at the same time. When they do this the two long tail feathers are brought down under the stomach and point forward; we doubt if they help any in flight, for they may switch them to one side or the other without any effect on the direction of flight. This dance always goes on from 11:00 a.m. until 2 or 3:00 p.m. every warm day. They can even fly backwards on a calm day, when there is no wind to blow them backwards.

The young when full-grown have a gray beak and are mottled black and white, but do not have the two long tail feathers. One day we were teasing a young bosun bird that was about 10 inches long. Suddenly it seemed as if it were turning itself inside out. It was really throwing up a partly digested needle fish (small gar) that must have been wound up like a clock spring inside the little bird's crop. The fish was twice as long as the bird!

The Frigate Bird or Man-of-War Bird:

By far the best flyer of all the sea birds is the frigate bird. Hour after hour, day after day he hovers on tireless, almost motionless wings, high in the air over the Island, waiting for the boobies and bosun birds to return from sea. Whenever he sees one of these birds returning, heavily laden with a crop full of fish, down he swoops on it at a terrific speed, and gives chase until it disgorges its meal. He then swiftly swoops again and grabs the disgorged fish, before it hits the ground or the sea, and eats it himself. That is one way to get a hot meal! The booby dodges, and croaks its objection to such treatment, but invariably must eventually "give up" to its enemy. The bosun bird also dodges and squawks in protest, but also must finally donate its share to this robber of the skies.

The frigate bird is the eagle or hawk of the sea. It is a large black bird with two long tail feathers. The beak is very long, hooked, and powerful. Adult males are an ugly yellowish brown on the under side, and during the mating season they can puff out their chins into ugly red pouches as large as a child's head. In the female the neck and breast are white.

Although frigates prefer to obtain their food "secondhand" they can also fish very well for themselves, snatching surface-swimming fish directly out of the water while on the wing. Frigate birds usually fly with the two long tail feathers slightly spread, or forked. They fly by soaring instead of flapping the wings like most birds do—they rarely flap their wings. They are experts at finding and taking advantage of rising warm air or updrafts, over the Island. They can often be seen apparently motionless, or slowly circling at a height of about 1,000 feet over the Island, where they are waiting and watching for bosun birds or boobies to return from sea with full crops, or they may be "spotting" some young tern. A frigate will swoop down, without touching the ground, pick up a young tern in its beak, fly up in the air to a height of over a hundred feet, and then toss its victim up into the air and catch and swallow it in one gulp! These cannibals may devour 8 or 10 terns a day.

Frigate birds are the only birds leaving or arriving at Midway in mass formation. This arrival or departure is rarely seen, possibly because they leave either very early in the morning or at night.

On December 29, 1938, a large formation of frigates appeared above Midway. They were coming from the southeast and flying directly into the wind which came from the northwest. Kure or Ocean Island is the only island to the northwest of Midway—they must have been headed for it. They formed a line 3 to 5 abreast for as far as the eye could see in both directions. Five hundred birds were counted, but some had already passed, and they were still coming when the observation was discontinued. They flew into the wind at a height of about 2,000 feet without any apparent movement of the wings or feathers.

We have never seen them attack a gooney, not even the young goonies.

Fig. 15. The frigate bird or man-of-war bird with young.

In spite of its great size—wing spread of 6 to 7 feet—the frigate is a comparatively light bird, weighing only from 5 to 6 pounds.

We often know when the frigates are going to leave Midway because early in the morning when they are preparing to leave, they all form together in a loose formation and circle around over the Islands. Nevertheless, the actual departure or arrival is rarely observed.

The frigate birds build very crude nests of sticks in the Scaevola bushes. The young are very ugly "critters," being more or less dirty, mottled rusty-brown in color. When approached they stare at one with a malevolent insulting air, and viciously strike with their long beaks.

The Boobies or Gannets:

There are 3 species of boobies or gannets at Midway—the red-footed booby, the blue-faced booby, and the brown booby. They are all smaller than the goonies, but larger than the bosun birds. They can be distinguished from all other sea birds by their exceptionally short legs. They always look like they are standing in a hole, or have had their legs sawed off! It just doesn't seem right for a bird to be built so close to the ground.

Boobies can maintain their balance on the wildest of rolling, pitching buoys, no doubt due to their low center of gravity. They have a perfectly streamlined body and are real amphibians, that is, they can swim as well as fly, and fly as well as swim! In addition they are one of the most perfect high divers in the world; pelicans are clumsy affairs in comparison. (There are no pelicans on Midway.)

The booby flies along at a height of 50 to 100 feet above the surface of the sea looking for fish. It flaps its wings more than does a gooney. When it spots a school of fish, near the surface, it pulls up into the wind, lowers its head, looks from side to side, chooses the fish it wants, folds up its wings and "power dives" on the victim. It almost always gets the poor fish. The booby swims so fast under the water that when it comes up out of the water it emerges at an angle of 45 degrees

Fig. 16. The boobies or gannets.

—on the wing—and is in full flight. It does not have to run along on the water like a gooney does.

Boobies also build crude nests of sticks and leaves in the Scaevola bushes. The young are funny, ugly, fuzzy, yellow rascals which should be approached with care, keeping well to the windward. They may turn loose a shower of filth on you, which brings to light an amazing thing. Although the air over the Island may be filled with countless thousands of flying birds, such as goonies, terns, and moaning birds all of which excrete while on the wing, they rarely make a "direct hit" on the poor lowly humans below. How these marvelous fliers must look down on those poor creatures that are earth-bound!

The adult blue-faced booby is black and white, with a blue-gray, yellow, or more often greenish yellow pointed beak; skin of face is blue-black, very dark. The feet are olive-drab or bluish gray in color.

The red-footed booby is also black and white; its bill is light blue with brown tip and red base, and the naked skin on its face is blue. Its feet are red and smaller than the above species.

The brown booby is the most common at Midway. It appears to be all black, but may have a gray or white stomach. Its bill is yellow, or bluish white, and its feet are pale yellow. This species is often seen perched on the railings of the docks at Midway, or upon pilings.

Boobies can dive to a depth of 90 feet! They have been caught in nets at this depth.

White Gooney or Laysan Albatross:

Best loved, most amusing, and always spectacular are the white goonies on Midway. This beautiful bird—large as a goose, with snow-white breast, neck, and stomach, delicate gray shading around the eyes, "Charlie Chaplin" gray feet, dark gray back, intelligent, bright shiny black eyes, and long powerful curved yellow beak tipped with gray, and with dark gray or nearly black wings—is the most popular bird on the Island.

By unanimous vote of all persons on the Island this is the king of birds. Not only is he a king, but also a clown. He is not afraid of anything, not even the great caterpillar tractors, autos, or people. Always polite, he rises and bows to you when you pass near him. True he may viciously snap his beak at you, but that is only a warning, and don't go too close, or that powerful beak will take off a finger, or cut a long gash in your arm or leg. You don't believe me? Just try it! With that organ of destruction he tears large, live squid and cuttle fish to pieces, and swallows hunks as large as your fist.

Why are these big birds so tame, so friendly and brave? Simply because for thousands of years there has been no animal or bird on the Island that could harm them. Some, but not all, are extra friendly. These individuals may be slowly, closely approached and petted, or scratched on the side of the cheek, or the back of the neck. They love it, but be careful; don't frighten them by any quick movement, or you shall pay dearly for it.

In the air the white gooney is one of the most graceful of birds. How easily they glide back and forth over the waves or over the sand dunes in the wildest of

storms without apparently moving a wing. But what a change occurs when they land. On land they are clumsy and waddle along ducking their heads and leaning from side to side with every step, their big webbed feet going plop, plop, plop. Like a plane they need a long runway into the wind in order to take off. Only when

Fig. 17. Laysan albatrosses or white goonies: above, adults; below, mother and young.

there is a strong wind blowing can they take off easily with a short run of from 15 to 20 feet. In calm weather they must run for a hundred yards or more and get up plenty of speed, their feet throwing up a shower of sand before they can really get under way. But once in the air they are most graceful and the master of this element. Their great wings have a spread of from 6 to 8 feet, and they are sometimes mistaken for a clipper plane coming in over the horizon. They rarely flap their wings like other birds, and then only to assist in getting up speed for the take-off, or occasionally on very calm days when there are no air currents to aid them.

When the goonies first return to the Island they are big and fat and clumsy. For 3 months they have been out at sea and have been accustomed to landing on water. Their first attempts at landing on a hard surface are comical. One comes in at full speed, then down go his flaps (feet), the tail drops, and as he reaches "stalling speed" his wings shake and quiver. He then hits, and hits hard. He has forgotten to take the brakes off! On water he simply elevates his toes and skids along. On land this doesn't work. He forgets to run and over he goes on his breast, with face and beak scooping up sand as he skids along on his stomach or even does a somersault. Then up he gets, looks around to see if anyone has seen him make that crash landing, shakes the sand out of his mouth, snaps his beak, raises his head skyward and gives himself the Bronx cheer! Then over he goes to some of his friends, bows a couple of times and sits down to rest and wait for the others to come in.

The males usually return first, and sit around waiting for the females to arrive.

Fig. 18. Laysan albatross or white gooney on nest.

By November 15 nearly all of the males have returned, and a few of the females.

After mating is over the dancing begins. The gooney dance has nothing to do with mating. Although an occasional pair may be seen dancing during the mating season, it really doesn't get started until after the mating season is over, and then it lasts all through the nesting season, slacking off when the young are nearly full grown. At this time it keeps the old birds constantly working to feed their young and they do not have time for the lighter things of life.

The goonies are very polite birds, and almost invariably bow to each other when they meet. This usually starts the dance. First they bow several times, then they "fence" with their beaks, rapidly knocking them sidewise against each other's, then they very rapidly snap their beaks, making a popping noise like the rattling of African bones, or a machine gun, or the roll of a drum. They then shake their heads rapidly from side to side at the same time giving a cry like the whinnying of a colt, a kind of a high shrill whistle. It is a wonder they do not addle their brains with this rapid shaking of their heads. The next motion is to partially spread one wing, scratch themselves under the "arm pit" with the tip of their beak like a dog biting fleas, and then stand on tiptoes with head and beak stretched skyward as far as they can reach. In this attitude they give the well-known Bronx cheer or raspberry. Sometimes this sounds like a sick cow mooing, at other times like a calf bawling. They again proceed to bow and nod rapidly in unison, and repeat the entire procedure, but with infinite minor variations. For this reason one is invariably compelled to stop and watch this fascinating dance. It is always good for a long laugh.

Fig. 19. Laysan albratrosses or white goonies in typical dance pose.

Usually a pair dance together, then a third edges in and all three dance together. This will sometimes cause a fight, the intruder often being attacked by one of the two original dancers. During the mating season there are many fights between males desiring to court the same female.

Sometimes these fights are very vicious affrays, at other times they last only a few moments, with one or the other running away with his swift comical waddle, and wings spread for balancing. When a real vicious fight is under way they strike at each other's eyes, mouth, tail and wings, trying to obtain a painful hold, which they keep with a bulldog tenacity. Sometimes one is able to insert the upper portion of his long powerful beak deep down the other's throat. The needle-pointed, downward-hooked beak slits the throat, sometimes cutting the jugular vein and causing death.

During all this they are madly screaming at each other in a high shrill squeal. If not killed, the loser runs off squealing with wings spread. The winner raises his head and gives the loser a loud derisive squawk. Very few birds are badly enough hurt during these fights to cause death; however, they may be bloody affairs, so that the beak, face and neck will be splotched with blood. When the loser runs away, he is usually pursued a few yards by the winner.

Occasionally, after most of the mating is over, one may see 7 or even 8 goonies dancing together. Usually however, not more than 2 or 3 are in a group. This dancing continues throughout the year from December to July.

All species of goonies do a somewhat similar dance, but each has its own routine.

After mating, the serious matter of nesting is considered by these birds which seem almost human, although after mating they often go to sea again for a short

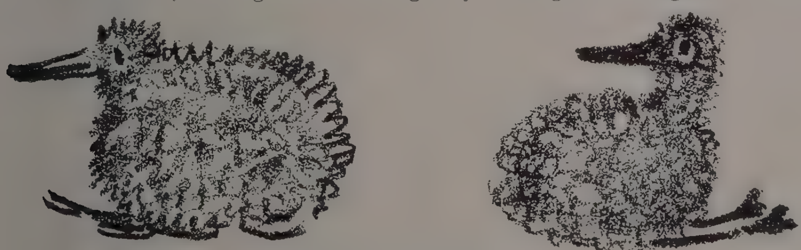


Fig. 20. "What's doing?"

Fig. 21. Attempted "take off."

time (about two weeks) before starting nest building and egg laying. A pair will wander off together looking for a place to nest. At this time the sounds they make are quite distinct from any made previously. It is evident that they are seriously discussing the important matter of locating and building the new nest.

The male calls the female over to the place he likes with a shrill trilling whistle, his body shaking with effort. Then he ducks his head several times, picks up a few pieces of grass or leaves in his beak and drops them around him in a circle. Then he says "ah! ah! ah!" in a wheedling tone of voice, as if to say "mamma, here is a good place!" So mamma comes over near papa and also begins to indiscriminately scatter grass and leaves around the countryside, in a hit or miss fashion. Then she decides that that isn't such a good place, and moves over a foot or two, and they both pull up some more grass and scatter it around. At the same time she will scoop out a shallow bowl-shaped depression with her feet, for which purpose she has a handy set of sharp claws on the ends of her toes beyond the webbed portion of her feet. You can receive nasty scratches from these claws if you are careless in handling the birds. Nest building begins in earnest just a day or two before the egg is to be laid. However, we have seen a female come in, land, go immediately to what she feels is the proper place, scoop out a hollow, line it with leaves and trash, build up the edge into a crater with sand, and lay the egg, all in the space of only a few hours.

The male may or may not be present. Usually he waits around for the female to come home. Then he assists her in building the nest. Part of the time he pulls weeds and drops them where the female can use them, at other times he drops the grass and weeds any place, or even takes them away from the nest and drops them farther away out of reach of the female. In this way he may be more of a hindrance than a help in nest building. Often they build more than one nest before permanently settling down in the last one made.

Soon after the egg is laid the male gently pushes the female off the nest and in turn sits on the egg for 2 or 3 weeks. In the meantime the female goes out to sea fishing. They change off on the egg about every 18 days. During this time, while sitting on the egg they neither eat nor drink.

There is a great deal of difference in the characters of different birds, fully as much difference as there is between individual humans. Some are calm and collected, being quite tame and friendly. These may be approached quietly, and petted or scratched on the back of neck or top of the head or cheek, without their becoming

Fig. 22. "Take off."

excited and biting one. Others are nervous and temperamental, and will viciously snap long before one gets near them. Some build a nice, big, high crater for a nest. Others build no nest at all, but lay their egg in only a slight depression in the sand, without bothering to line it with leaves and sticks. One of a pair will sit on the nest picking up one beak full (½ teaspoonful) of sand after another (all day long) and piling it up around the edge of the nest, at the same time carefully patting it down firmly with the side of the beak. Thus a very fine high nest, a perfect miniature crater is built up. Then the mate will come in, take its turn, and sit there and do nothing but sleep most of its 18 days on the nest. As a result the nest slowly goes to pieces, being blown away by high winds, or washed away by heavy rains.

The egg is very large, being 8 to 9 inches around the shortest diameter, 10 or 11 inches around the long way. It is oval in shape, smaller at one end, and weighs 8 to 9 ounces! That is a rather large egg for a bird that weighs only 6 or 7 pounds.

After the egg is dropped, the bird reaches down and touches it all over with the tip of her beak. Then she talks to it saying "ah, ah, ah," then gives a loud squawk and covers it with her body. Sometimes within an hour or two the male gently pushes her off the egg and takes her place. This change always takes place only after considerable "talking it over." The one on the egg always hates to leave it. Sometimes the male does not appear for a day or two to relieve the female, but usually the change occurs the same day the egg is laid.

The first white gooney appears about November 1. It comes in and rests for a day or two, but soon gets tired of sitting around by itself, and goes out to sea again. From November 7 to 10 a few more appear and wait for others to come in. The first egg is laid about November 20 and by this time about 60 per cent of the goonies have returned to Midway. By December 5 most of the eggs have been laid, and on January 25 the first egg may hatch. By February 10 almost all the eggs have hatched, with only about a 5 per cent failure.

Sometimes a bird sitting on the egg gets tired of waiting for the mate to come in and relieve it so it leaves the egg. The egg may be left exposed for several days. Then one or the other returns and sits on it. Some eggs have been left uncovered for 4 or 5 days, but hatched just the same. Occasionally during the last month before the egg hatches one mate fails to show up to take the other's place. In such a case the bird on the nest may remain on the egg for as long as 30 days or until

Fig. 23. "Three-point landing."

it hatches. That is a long time to go without food or water, except for the few drops of rain water that may fall into the narrow beak. It takes 9 weeks for the egg to hatch—a long incubation. Most birds' eggs hatch in 3 weeks.

The adult bird covers the young newly hatched gooney for another week or 10 days before leaving it. By this time it is so big the old bird has difficulty covering it. From then on, for 5 or 6 months, the old birds feed the young one by regurgitation. This is a somewhat painful process for the adults.

Nearly all the sea birds drink sea water. In hot weather they can be seen flying low over the ocean dipping up water in their beaks. This is especially noticeable with the terns, which form a constant stream flying from the nesting grounds, out to sea, near shore, where they dip up a few drinks and then immediately return to the nest.

When the older goonies return to feed the young, they plainly recognize their own babies, and the baby distinctly recognizes mamma or papa. All young goonies, and all old birds look alike, at least to the human eye. However, the babies start to cry "peep-peep-peep" and beg for food the minute their own parent appears on the scene. After feeding the young, the old bird rests for a short time, a few hours or maybe over night, then again goes out to sea fishing.

When the babies are 2 or 3 months old they begin to wander from the nest and pick fights with each other. If one of the parents returns and finds the nest empty, it looks around until it finds its own young one and then proceeds to give it a good beating, by pecking at its neck and back. The young one bows its head, hiding its face and beak in the breast feathers. The little fellow seems to know he had no business being away from the nest, so as soon as the old bird stops trouncing him, he runs home. Then, and then only will the parent feed him. If he lets out another peep before reaching the nest, he receives another beating.

Sometimes a young one that is starving will beg food from an old bird that is not its parent. He always gets a terrific beating, but never any food. This is especially true later on, in July and August, when the young are nearly full-grown, and some of the old birds fail to return to feed their young. About 5 per cent of the young birds die from starvation at this time. Between the ages of 1 month to 6 months about 10 per cent of the young die from disease, starvation, or by drowning in low-lying areas during floods.

When first hatched, and for 6 or 7 months the young is covered only with a layer of fine fuzz, dark gray in color. This fuzz is lost and slowly replaced by

Fig. 24. "Two-point landing"

the regular adult plumage during the last two months they are on the Island. Later they have all adult plumage except for the ring of dark gray fuzz around the neck which gives them a very comical look.

When the old goonies think it is time to leave, they go. The young are left to learn to fly by themselves. They learn by trial and error, mostly error at first. When they are about 7 months old (in July) we have occasional summer showers. Every time it begins to rain it blows, and all the little goonies stand up, face into the wind, spread their wings and violently flap them up and down. This develops their wing muscles. It looks like a lot of umbrellas going up. By this time the wing feathers are more or less fully developed. As the muscles get stronger the young birds hop up and down in the same place, then take a few steps forward into the wind. If a violent gust of wind hits them they may even leave the ground for a few feet. They are often blown over backwards, and land in a heap, much to their chagrin. Sometimes they go into a nose dive, and hit with an awful thump, but they are tough and can "take it." They get up squawking and try all over again—it is very laughable. Pretty soon they learn to run quite fast with wings widely spread and flapping with all their might. They reach an altitude of 8 or 10 feet, look down, get scared, fold their wings, and down they come and hit hard. It may knock the wind out of them, but they soon try again. It takes them about a month to learn to fly—then away they go.

During the latter part of July and the first two weeks in August very few old birds are seen on the Island. They are too busy feeding the young ones to put in their time loafing on land. They come in, feed the young and go right out to sea again. That is why some people think the old birds leave several weeks before the young birds have become full-grown. However, by August 15 all the old goonies have left, and most of the young ones. Only a few starved, sick ones are left on the beach where they have wandered. These usually die. Many drown in the lagoon and are eaten by sharks. We have seen an 18-foot shark gobbling up these weak young birds. They cannot take off from the water. Baby goonies

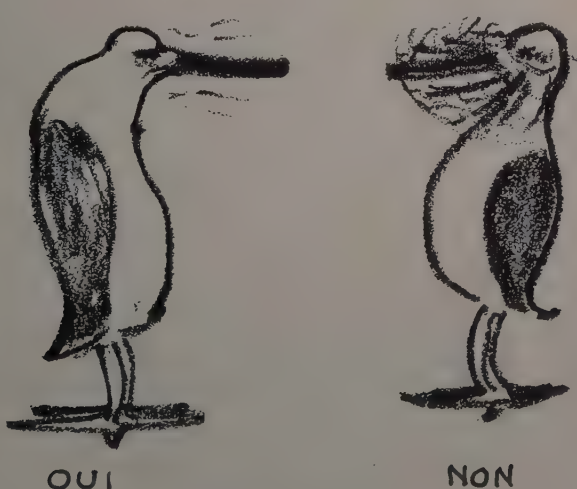


Fig. 25. "Dancing."

are in some respects very much like human babies. As soon as they can shuffle around on their elbows they pick up everything they can find, in their mouths and chew on it. They appear very intelligent with their bright, shiny, black eyes, and "cocky" ways. Some of them are very shy, and hide their heads as if in shame when approached. Others sit up high so they can see better and snap at you— when you get too close. Still others will gently nibble at your fingers. When young they cannot bite very hard. A few of the young ones can be taught to eat out of your hand, and they will gobble up anything offered them. Best of all they like sardines and canned salmon, but they also gulp down pieces of steak, ham or even a whole bun. The bun will stick in their throat and they have to pump it down.

That old goonies eat mostly squid or cuttle fish is proved by what they throw up. This is the remains of squid and cuttle fish, occasionally parts of flying fish or mullet, and some stones. These stones are very light in weight, being a pale, gray pumice filled with thousands of little air bubbles. We have not yet been able to determine where they get these crop or gizzard stones, possibly some place near Japan.

A California zoo obtained permission to capture and import into San Francisco 4 live goonies. Four full-grown, young white goonies were caged, and sent in by clipper. One died on the way, and one died soon after arrival. Food had to be forced down their throats, and after a few months the remaining two died. It is said that birds in this family have never been kept alive in captivity. Very likely, when the time comes for them to go on their annual vacation, they must do so or perish.

No young ones ever stay on the Island until the old ones return again. All have left Midway or died by August 20. From August 20 to October 12 or 20, no goonies are seen at Midway, not even at sea!

Fig. 26. "Dancing."

In July, 1937, 90 young birds were banded. None ever returned to the Island. One was taken aboard a Japanese fishing boat 300 miles from Japan on December 12, 1937, about 2,000 miles northwest of Midway.

Goonies possibly live to be from 15 to 20 years old. There must be about 20,000 white goonies at Midway. There are over 2,000 on the P.A.A. compound by actual count.

Fig. 27. "Dancing."

The Black Gooney:

The black gooney or black-footed albatross is the other species of gooney found on Midway. It is nearly all black, or dark gray with a brownish sheen to the feathers, and with black beak and black feet, and white under the tail.

The black goonies return about two weeks ahead of the white ones, usually between October 15 and October 25, and they leave earlier, all having left the Island by August 1. Both species are about the same size, lay the same size eggs, and feed the young in the same manner. However, the black goonies prefer to nest around the edge of the Island on the sand of the beach, at some distance from the water and beyond the reach of high tide. The white goonies prefer to nest inland.

The black goonies dig a deeper hole in which to nest. Often during violent sand storms the young ones become completely covered up, or have just their heads and necks sticking out of the sand. They die if they are not dug out. The parents apparently cannot, or do not dig them out when thus buried. There are more black

goonies on the Island than white ones—possibly some 30,000 individuals. They seem to be hardier than the whites, but a white will outfight a black one nearly every time.

The black goonies have a different kind of a voice than the whites, it being deeper and coarser. At times they sound much like the honking of geese or the quacking of ducks.

They dance more rapidly than the whites, and when a white and black try to dance together they soon get out of tune or rhythm, so one or the other soon walks away in disgust.

They very rarely inter-breed, as a matter of fact we have seen only one bird, a light gray in color with partly white breast and neck, that may have been a hybrid.

Fig. 28. Black-footed albatrosses or black goonies, adults and young.

When walking, the black gooney humps up his shoulders, pulls in his head and neck, and walks with quite a swagger—he looks real mean. They are shyer and more nervous than the white species. They will frequently attack human beings when molested, and for this reason are not as well liked as the tamer white goonies.

Short-Tailed Albatross:

The only other species of albatross that has been seen at Midway was a single example of the short-tailed albatross, a much larger species fully 10 feet in wing-spread, with an even larger, longer, more powerful beak, and a very deep croaky voice. It returned for two years to the Island, and then for some reason was injured and died. For a while it was setting on a black gooney egg. It was a much more powerful bird than the other two species, and could be held only with difficulty.

The Gooney That Could Remember Where It Was When It Was In The Egg:

One day we noticed that a white gooney had made a nest right in the middle of the road. So little by little we moved the egg, a foot at a time, over towards the side of the road. One of the parents always followed and sat on the egg, until eventually it was established in a nest at once side of the road at least 30 feet from where the egg was first laid. Both parents took turns sitting on the egg in the new locality. The change didn't seem to bother them. Then the egg hatched, and the young one when about two weeks old was left by itself. The next time we saw it it was right back where the original nest had been made in the middle of the road. It could remember where it belonged!

What really happened was that the first time the old bird returned to feed it, it insisted that the young bird return to the old nest-site before it would be fed. The old bird probably went directly to the old nest and waited for the young one to come over.

This completes the list of sea birds that nest at Midway. Since they nest here, and spend from two-thirds to three-fourths of their time here, this may be considered their natural home, for they leave only for a short period of a few months, probably remaining at sea wandering widely in search of food, and following schools of fish that are being chased by larger fish, sharks, seals, porpoises or whales. Certainly the smaller fish lead a harassed life, being attacked from below by the predators just mentioned and, when driven up out of the sea, are snapped out of the air by the sea birds. The smaller fish eat tiny fish, and these in turn eat minute crustaceans, and tiny larvae of crabs and lobsters, which in turn live upon even lower forms of life, microscopic plants and animals such as Diatoms, Protozoa, Infusoria, Foraminifera and Radiolaria which are present in all sea water in countless billions.

The complete list of sea birds is as follows:

White gooney	Brown booby	Grayback tern
Black gooney	Sooty-backed tern	Bosun bird
Frigate bird	Hawaiian tern	Wedge-tailed shearwater
Blue-faced booby	Noddy tern	Bonin petrel
Red-faced booby	Fairy tern	Bulwers petrel

The Land Birds on Midway

The four species of land birds inhabiting Midway are canaries, pigeons, finches and rails, exclusive of domestic fowl. All have been brought here from some other place—pigeons are raised at the Cable Company, and canaries have been turned loose, and are semi-wild but fed daily.

The Laysan "Finch":*

The finch and the rail were brought to Midway from Laysan Island, a small island between Midway and Honolulu. They are indigenous—or natives of Laysan Island. The finch is a very poor flyer, quite tame, slightly larger than a sparrow, with a rich yellow breast in the male. The finch is the worst pest on Midway. It destroys the young shoots, buds and flowers of ornamentals, vegetables and other cultivated plants, and is very destructive in this way. It nests in the ironwood trees.

Fig. 29. The Laysan "finch."

The Laysan Rail:

On the other hand the Laysan rail, with short "stub" wings so small that it cannot fly, is insectivorous and certainly very beneficial. We have never seen it eat anything but flies, caterpillars, moths, and maggots. The Laysan rail is about 5 inches long, and stands about 4 inches high. The wings are so small they are hard to see, and then only when they are in a great hurry to get some place. It cannot fly at all, but is a very rapid runner. It is brown in color on the back, the whole under parts blue-gray, looks something like a small quail, has bright little red eyes and green beak, legs and feet. If you make no swift or suddent movement, but sit real still they will come right up to you and run around and between your feet, looking for flies. They pick flies right out of the air! But more often they stay around broken eggs or dead birds getting the flies that are attracted to the

* The so-called Laysan Finch is actually *Telespiza cantans*, a member of the endemic Hawaiian family Drepanididae. The true finches belong to the Fringillidae.

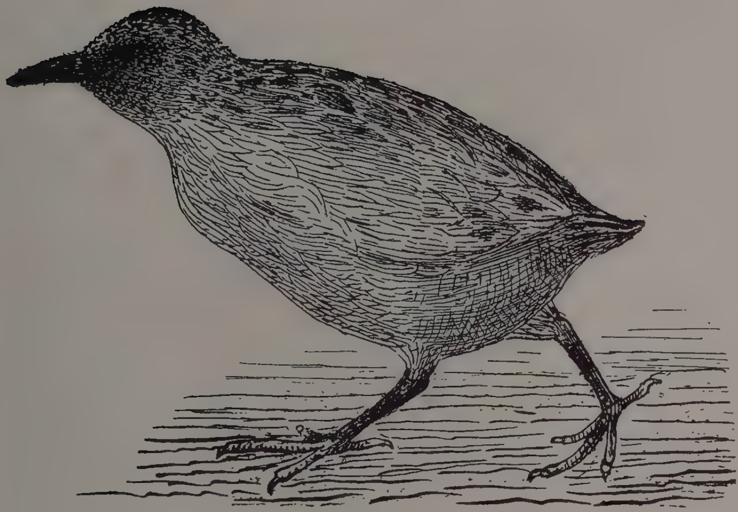


Fig. 30. The Laysan rail.

carrion. When the maggots are emerging and going into the ground to pupate, the rails dig them up by flipping the sand sidewise with the beak. They also diligently search all grass and other plants looking for caterpillars and moths which they relish. The rail may be considered the most beneficial bird on Midway.

The Laysan rail is about one-third the size of the Wake Island rail. The Wake rail is also flightless and is a native of Wake. It is a distinct or different species from the Laysan rail.

During the breeding season our rail becomes somewhat noisy. For its size it can make quite a racket, a good term for its peculiar chattering cry. It nests on the ground, hiding the nest in the grass or bushes, and lining the nest with grass. The egg is about 1⅛ inches long; two or three may be laid. The baby rail, only an inch long, when 4 or 5 days old, can run as fast as the older birds. It soon learns to find its own food, as it is taught to do so by the older birds which carefully guard it for the first month. When only 2 or 3 days old the little rail looks like a black velvet marble rolling along the ground. Its little feet and legs are so small and move so fast that they can hardly be seen.

Migratory Shore Birds:

Although the nearest large body of land in any direction from Midway is 2,000 miles away, there are certain land birds that regularly stop at Midway on their way to the larger Hawaiian Islands and Samoa.

Most commonly seen prowling around on the lawns of the P.A.A. hotel is the Pacific golden plover which comes down from Siberia, the Aleutian Islands, or Alaska. A few may stay here over the winter. Others go on down to Samoa, Tahiti or even perhaps New Zealand—another 4,500 miles! They must fly "non stop" the entire 1,600 miles from the nearest Aleutian Island to Midway. They do not have webbed feet, and cannot stay on the water for more than a very short time without drowning.

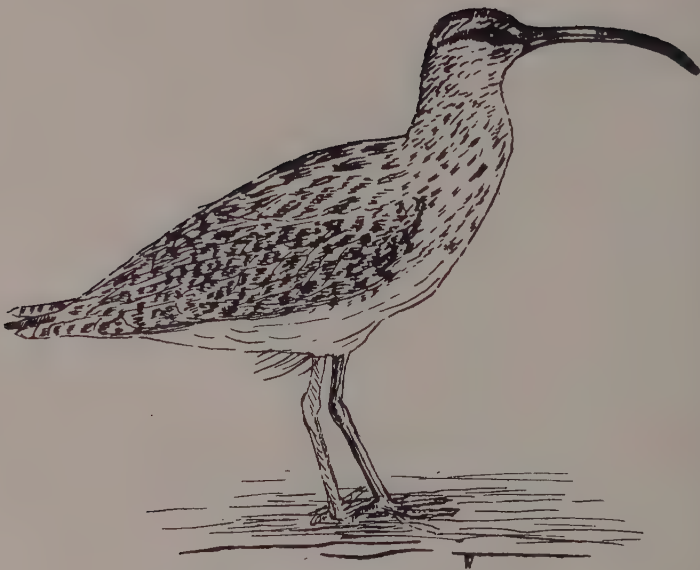


Fig. 31. The bristle-thighed curlew.

Also regular migrants are the "wandering tattler," "turnstone" and "bristle-thighed curlew." The latter is the bird with the long, downward curved beak, which is almost as long as its body. It is as large as a small chicken, but has long legs. Its cry of "Kee wee—Kee wee" when disturbed is distinct from all other bird cries.

Storms Bring Strangers:

The strong winds, often 30 to 60 miles per hour, of our frequent winter storms from January through April, often "blow in" strange birds.

These include several species of wild duck, bittern, hawk and goatsucker (night-jar or whippoorwill). They are often captured, being too tired upon arrival to try to escape. Most of them die after a few days on Midway.

Two species of sea gulls are also blown in by storms, but they stay only a few days.

Large dragon flies, and the monarch butterfly, also appear in fairly large numbers after storms. They all die off in a few weeks' time.

Fish-net floats, glass balls from 2 to 18 inches in diameter, wash ashore during storms. Some have Japanese characters, other have the Russian hammer and sickle impressed in the glass.

In August or September the stinging Portuguese man-of-war, a small blue jellyfish, may appear. It is best not to go swimming if they are present in large numbers.

Acknowledgments

I am indebted to Walter Donaghho of Honolulu for identifications of some of the birds mentioned in this article.

G. C. Munro of Honolulu furnished the pictures of the huts and Capt. Walker's house on Midway.

Dr. F. X. Williams of Honolulu made all of the pen and pencil drawings, from life while at Midway.

The crayon cartoons were made by J. C. Littig of Manila, while on the California clipper between Midway and Honolulu.

The Bishop Museum furnished the photographs of the boobies and frigate birds.

To the above and also to others who have helped me in writing this article I hereby express my gratitude.

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"The End."

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 17, 1941, TO JUNE 11, 1941

Date	Per pound	Per ton	Remarks
Mar. 17, 1941........	3.33¢	$66.60	Philippines.
" 18.............	3.35	67.00	Cubas; Philippines; Puerto Ricos.
" 19.............	3.34	66.80	Cubas.
" 21.............	3.32	66.40	Cubas.
" 24.............	3.425	68.50	Puerto Ricos, 3.40; Cubas, 3.45.
" 31.............	3.40	68.00	Puerto Ricos.
April 17.............	3.30	66.00	Puerto Ricos.
May 5.............	3.435	68.70	Puerto Ricos, 3.42, 3.45; Philippines, 3.45.
" 9.............	3.39	67.80	Puerto Ricos, 3.38, 3.40.
" 14.............	3.38	67.60	Puerto Ricos.
" 20.............	3.34	66.80	Cubas, 3.35; Puerto Ricos, 3.33.
" 23.............	3.33	66.60	Puerto Ricos.
" 24.............	3.38	67.60	Philippines.
" 27.............	3.375	67.50	Cubas, 3.37; Puerto Ricos, 3.38.
" 28.............	3.4075	68.15	Puerto Ricos, 3.395, 3.42.
" 29.............	3.45	69.00	Puerto Ricos; Philippines.
June 5.............	3.40	68.00	Puerto Ricos.
" 6.............	3.405	68.10	Puerto Ricos, 3.40; Philippines, 3.41.
" 9.............	3.44	68.80	Puerto Ricos, 3.43; Cubas, 3.45.
" 10.............	3.45	69.00	Philippines; Puerto Ricos.
" 11.............	3.50	70.00	Philippines; Puerto Ricos.

M. F.

THE HAWAIIAN PLANTERS' RECORD

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